Amateur Deep Space Reception

Equipment and Techniques

Written and presented by Paul – M0EYT

Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX'd so far
- Future
- Questions

Introduction: What is Amateur Deep Space Reception ?

- Amateur DSN is concerned with the detection of extremely weak signals from distant space craft
- S-Band and X-Band systems are most common, Ka-Band systems for 26GHz and 32GHz have been built and used
- A number of DSN group members are active Microwaver's
- Demodulation of science data is generally not performed
- A yahoo-group 'Amateur-DSN' is used as the focal point for activity, such as detection of newly launched space-craft, signal reports, and for general technical chatter.
- The Amateur DSN group is made up of <u>dedicated</u> weak signal enthusiasts, with the majority of activity being in Europe
- You should join this group too!

Introduction: Why would you want to do it ?

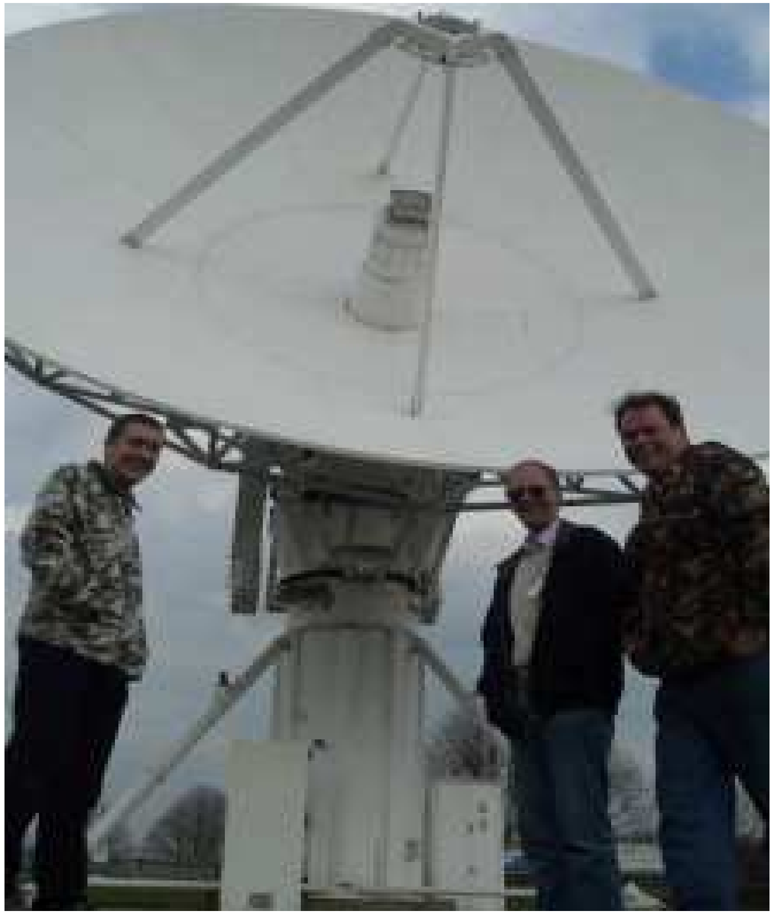
- Self improvement from a technical perspective – the real heart of Amateur Radio
- To learn about space craft orbital dynamics
- To learn how to build and optimise receive systems
- To improve home workshop practices
- To learn about high precision frequency and time standards
- To experiment with leading-edge software defined radios for weak signal detection
- To hear spacecraft millions of miles away from Earth, with home made equipment
- To have lots of fun doing all these things!

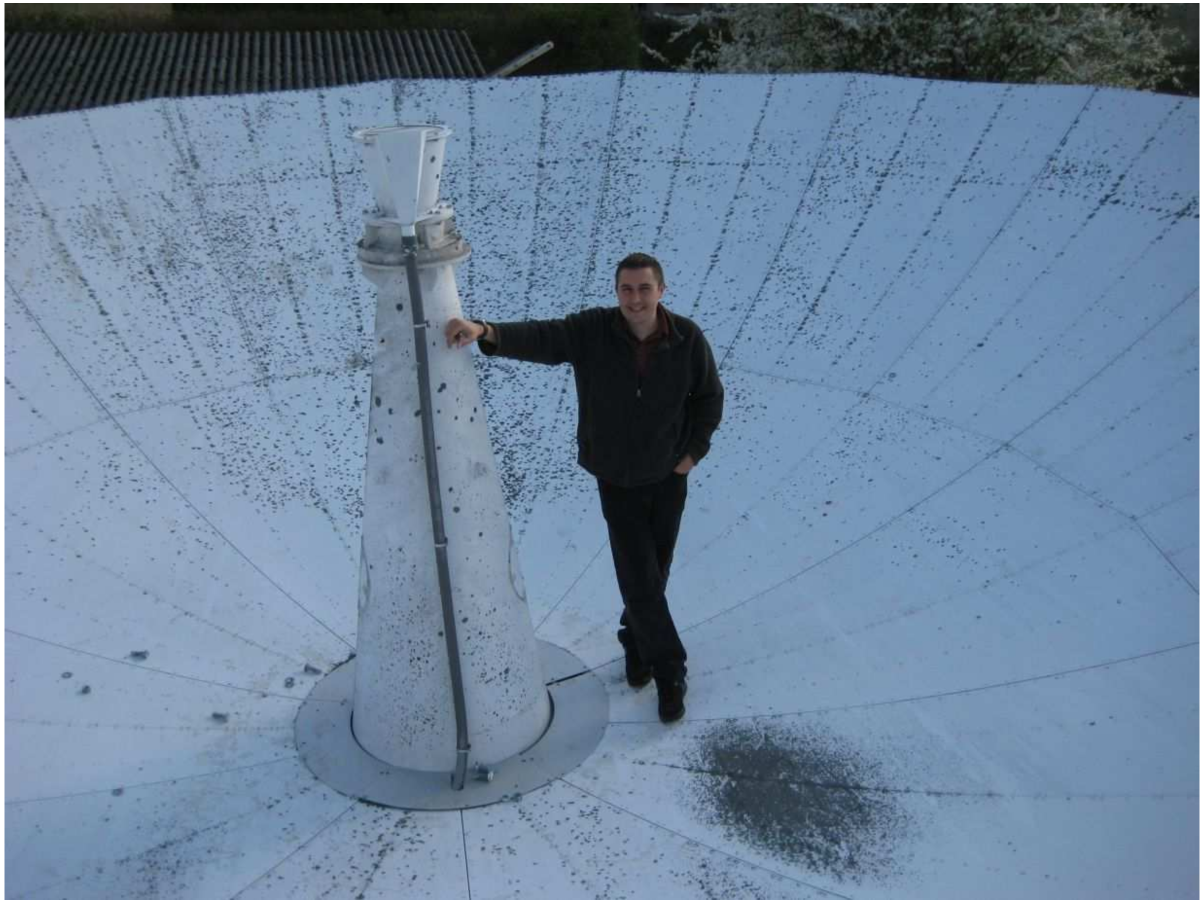
Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX'd so far
- Future
- Questions

My Background

I'm generally interested in radio > 1GHz in frequency; microwaves!
Spend most time detecting and cataloguing satellite downlinks from UHF to Ka-Band - 99% of my activity is receive only





My Background

Professionally, I work for an information security consulting company performing security testing and ethical hacking.

Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX'd so far
- Future
- Questions

The inspiration for this project

A demo of Amateur DSN reception was given at the UK Microwave group meeting, held at BT Martlesham in November 2005

The amateur satellite experts were on hand to give the demo; Freddy ON6UG and James G3RUH.

Venus Express and MRO were received live, during their cruise phases

The inspiration for this project

The Venus Express spacecraft was fairly close at 750,000 Miles

The Mars Reconnaissance Orbiter was just over 27,000,000 miles away and an easy copy on the 1 metre dish that was being used for the demonstration.

Following the demo, I had to repeat this at home! It is the ultimate in satellite DX.

The inspiration for this project

The other piece of inspiration came directly from NASA;

I am an Amateur Radio Operator, can I listen to the data coming from spacecraft?

Unfortunately, no. Spacecraft signals are very weak by the time they reach Earth which is why we need the huge reflector dishes of the Deep Space Network antennas as well as the sophisticated amplifiers and other signal enhancing electronics to hear them. Amateur radio equipment and antennas cannot receive such weak signals.

As can be seen from the website FAQ at http://deepspace.jpl.nasa.gov/dsn/faq-data.html – it clearly states that Amateur Radio operators **cannot** hear such weak signals….

Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX'd so far
- Future
- Questions

Professional DSN ground stations

NASA and ESA are the primary users of DSN frequencies, and have a fair number of Earth Stations around the world.
NASA has sites at Goldstone, Madrid and Canberra – each with at least 4 antennas, 1X 70m, 2X 34m and 1X 26m dishes. The sites are positioned with about 120 degrees of separation.




These antennas operate in the S, X and Ka bands. NASA are moving towards the 32GHz band for greater transfer rates.

Professional DSN ground stations

The ESA (European Space Agency) also has a fair number of ‘owned’ or ‘borrowed’ DSN tracking antennas, locations include; Cebreros (Spain), New Norcia (Australia), Maspalomas (Spain), Perth (Australia), Kourou (French Guiana), Kiruna (Sweden), Redu (Belgium), Villafranca (Spain).

Typical antenna sizes are 35m, 15m, 12m and 3m

Professional DSN ground stations

The gain of a typical DSN antenna is extremely high. Example for the Goldstone 70m antenna (used for tracking the Voyager probes etc);

Efficiency ~ 65%, Frequency ~8·4GHz
Signal gain 74dB = a gain of 25,118,864.3 over an omni antenna

1 watt of RF at the feed point would result in an ERP of 25MW!

The -3dB beam width of this antenna is only 0·04 degrees! A typical 3·7m dish has around 47dB gain which makes it over 500 times less 'powerful' than the 70m NASA DSN antenna.

A 3·7m dish is a nice size for Amateur DSN!

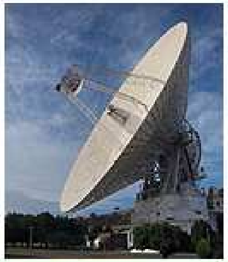
Professional DSN ground stations

Tracking Schedule

Each day the antennas are directed to receive or transmit data to any number of robotic spacecraft exploring our Solar System and beyond. This schedule is worked out months and sometimes years in advance by the mission controllers at the Jet Propulsion Laboratory in Pasadena, California USA.

At various times in the schedule, time is set aside for antenna calibration, maintenance, or engineering development tasks. Time is also set aside for radio astronomy projects and mission training simulations.

Below is the general antenna tracking schedule for the next few weeks, showing the spacecraft being tracked each day. A list of links to each mission is provided at right.


July 2012

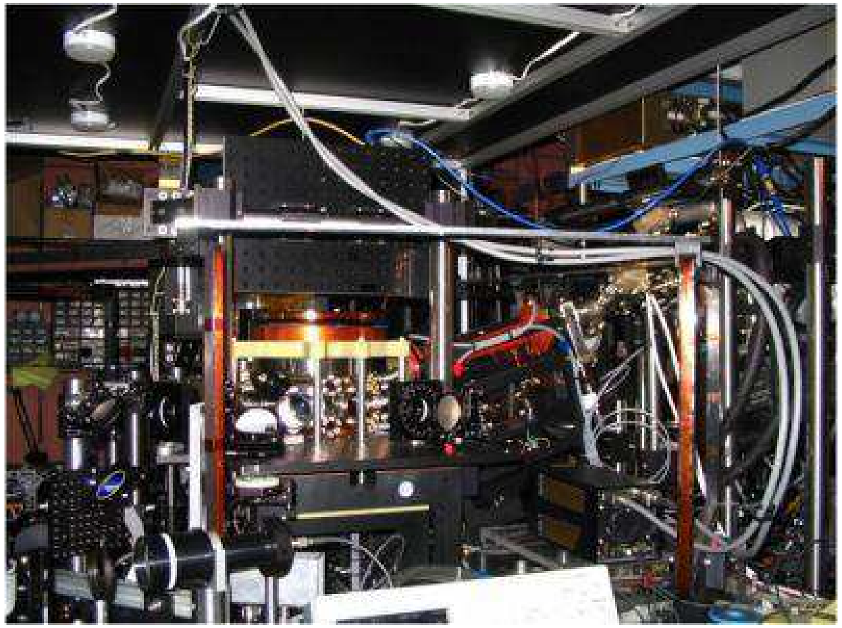
	DSS-34 (34-metre)	DSS-43 (70-metre)	DSS-45 (34-metre)
Mon 2	GRLA/ACE/SOHO MRO/GRLB	NHPC/VGR2 MarsO/MRO/NHPC	GRLB/DAWN MSL/GRLA
Tue 3	GRLB/CHDR/CLU/CLU4 SOHO/CLU2/MSL/GRLA	NHPC/VGR2 MarsO/NHPC	GRLA/GTL/DAWN CLU1/MRO/VGR2
Wed 4	GRLA/WIND MSL/GRLA	NHPC/SOHO CAS/GTL	GRLB/DAWN/MSGR MarsO/MRO/GRLB
Thu 5	GRLA/DAWN MSL/GRLA	GTL/VGR2/SOHO STB/MRO/NHPC	GRLB/MarsO/MRO GRLB
Fri 6	GRLA/VGR2 MSL/GRLA	NHPC/GTL/SOHO CAS/VGR2	GRLB/DAWN/STB MarsO/MRO/GRLB
Sat 7	GRLA/WIND/SOHO MSL/CLU2	VGR2/STA/SOHO MarsO/MRO/CLU1	GRLB/DAWN/ACE GTL/VGR2/CLU4
Sun 8	GTL/CLU1/DAWN MSL/VGR2	THB/CLU4/CLU3/GBRA SOHO/CAS/GTL	GRLB/MSGR/ACE MarsO/MRO/GRLA
Mon 9	VGR2/GRLB/SOHO MSL/GTL	GTL/GBRA/SOHO MarsO/MRO	GRLA/DAWN/ACE MarsO/VGR2
Tue 10	GRLB/SOHO/STB MarsO/MRO	DAWN/CAS VGR2	GRLA/DAWN MSL/GTL

Spacecraft Missions

ACE	Advanced Composition Explorer
Cass	Cassini
CHDR	Chandra X-ray Telescope
Clu	Cluster 1-2-3-4
DAWN	Asteroid Mission
DIF	Deep Impact
GBRA	Ground-Based Radio Astronomy
GRL A-B	Grail - Gravity Mapper
GTL	Geotail
GOES	Geostationary Operational Environmental Satellite
HST	Hubble Space Telescope
JNO	Jupiter Mission
KEPL	KeplerTelescope
LRO	Lunar Recon. Orbiter
MAP	Microwave Anistropy Probe
MarsO	Mars Odyssey
MER 1-2	Mars Rovers - Spirit(2) Opportunity(1)
MSGR	MESSENGER
MSL	Mars Science Laboratory
MEX	Mars Express
MRO	Mars Recon. Orbiter
MSPA	Multiple Spacecraft Per Aperture Testing
NHPC	Pluto mission
NOAA	Earth observation
PLC	Planet C - Akatsuki

Professional DSN ground stations

Professional DSN ground systems need reference oscillators of exceptional quality. NASA typically uses ION-Trap oscillators;



The result is a clock with an effective stability equivalent to about one minute in 10 billion years – the approximate age of the Solar System! Currently the most accurate Aluminium-ION clock keeps time to within 1 second in about 3.7 billion years.

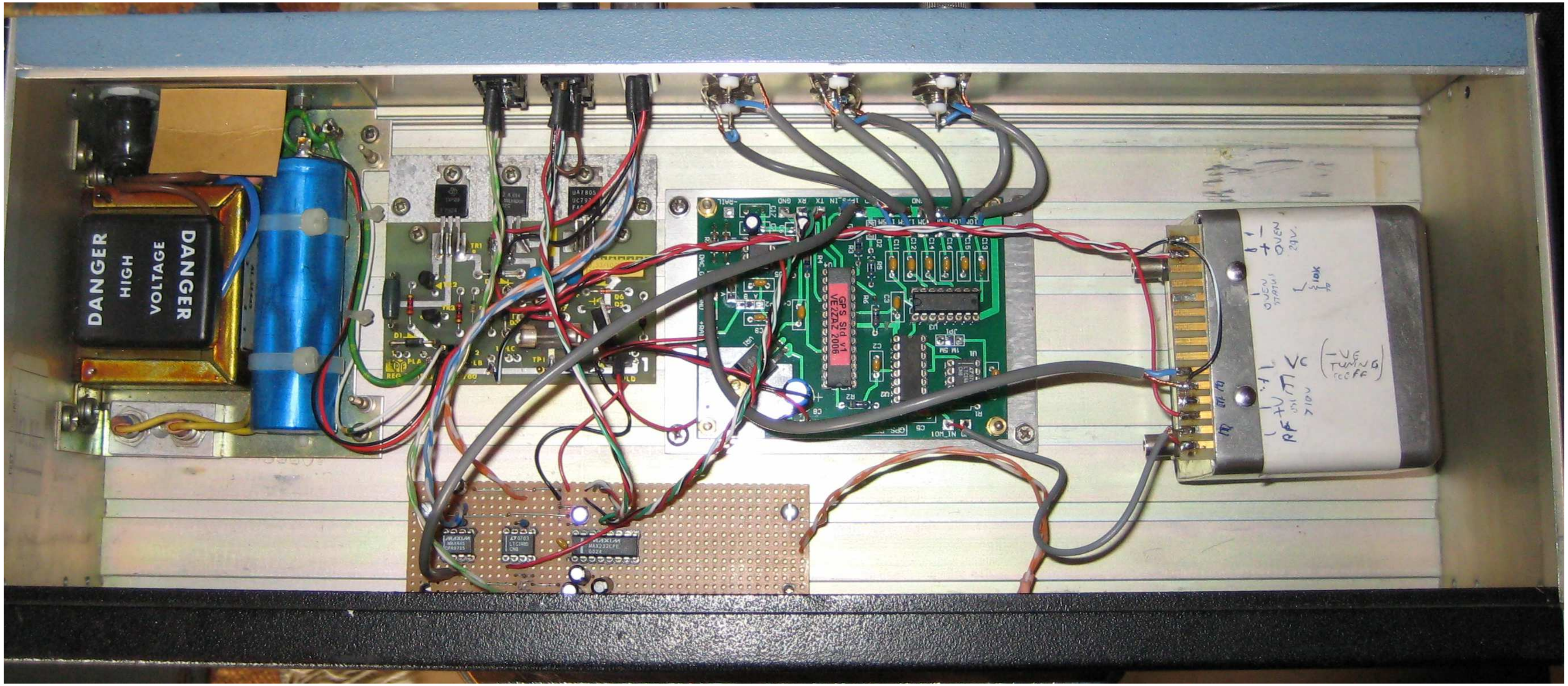
Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX'd so far
- Future
- Questions

Frequency References

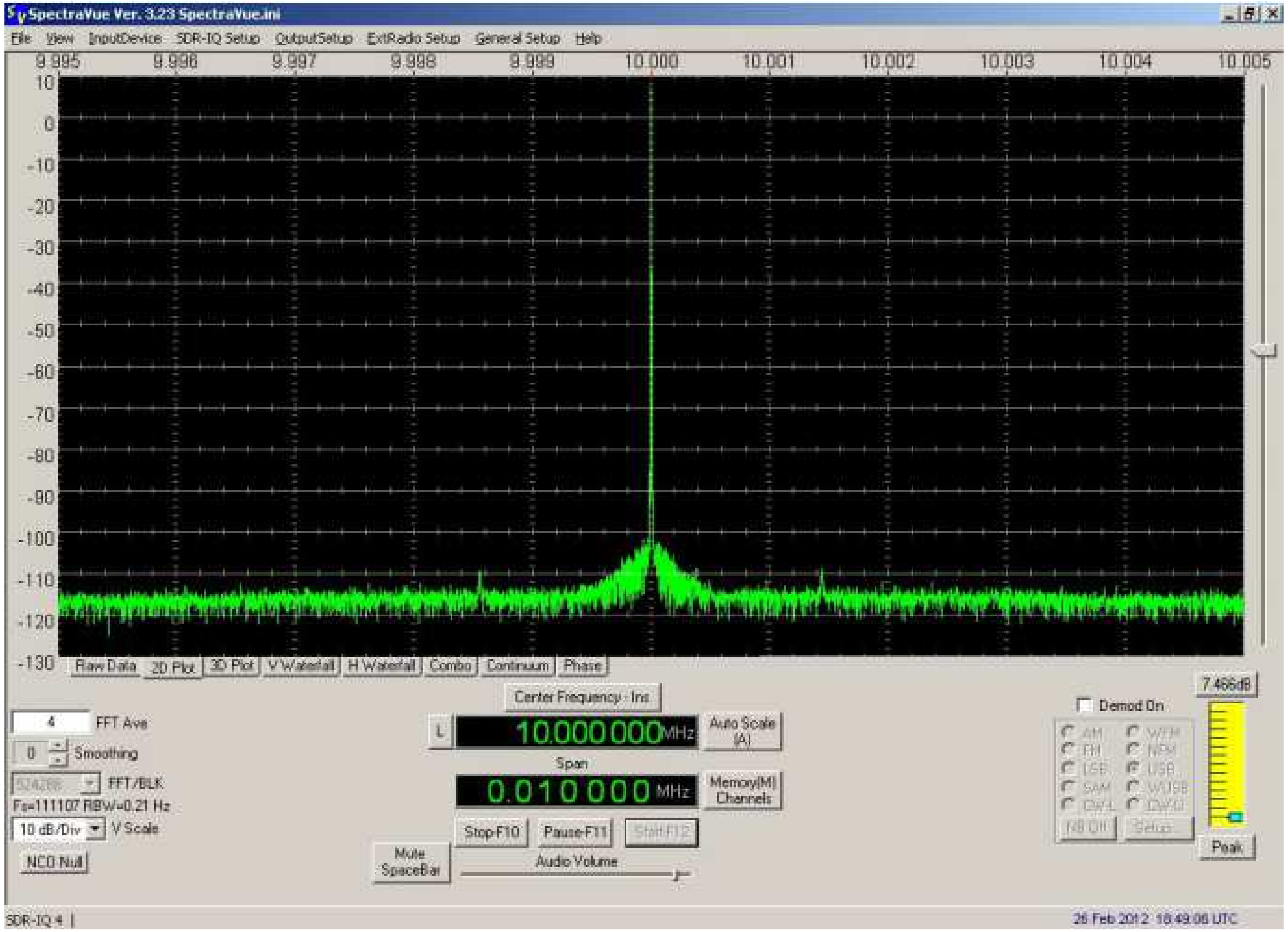
Since DSN signals can be extremely weak, it is important to know that you are tuning to the correct frequency at S or X band. This becomes even more important once you move up to Ka-Band.

GPSDO’s are easy to build with solutions such as the VE2ZAZ;



Frequency References

A clean 10MHz signal is very important especially if you are feeding PLL's / synthesisers or multipliers. The FFT plot below shows the M0EYT ZAZ unit centred at 10MHz with 10KHz span;



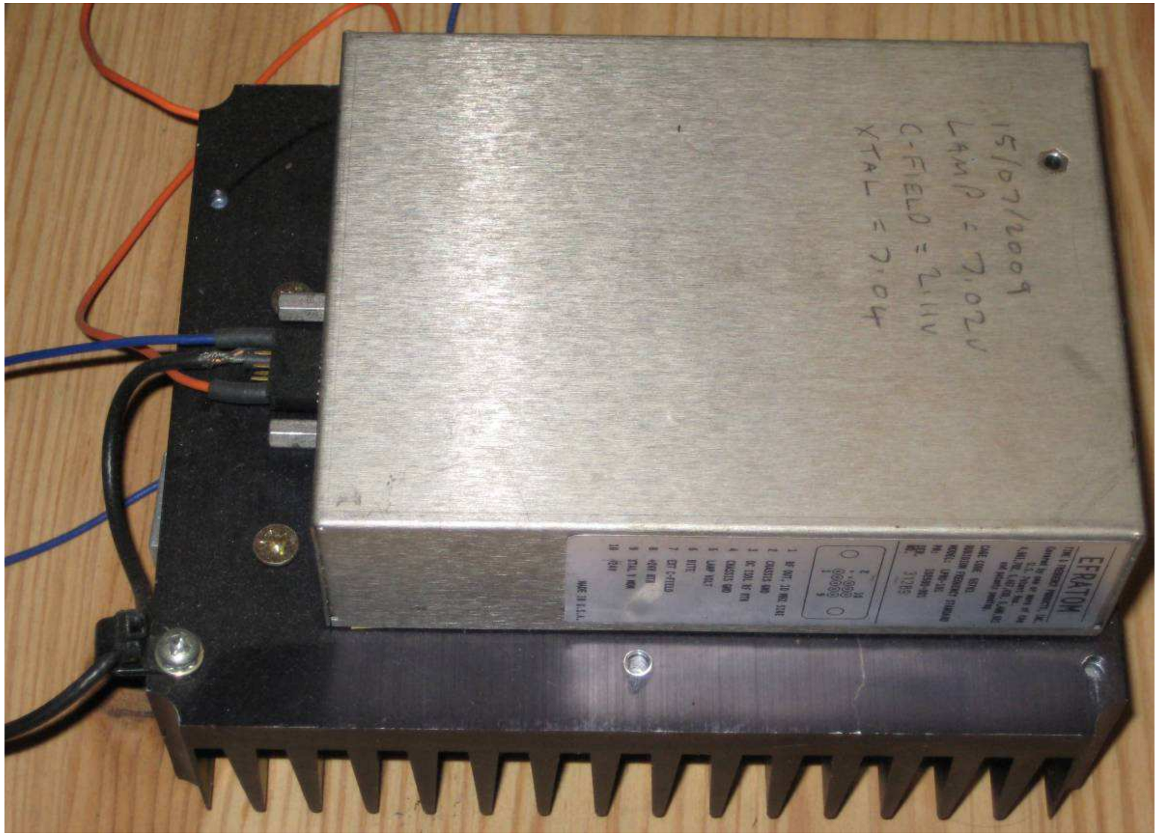
Frequency References

If you do not want to build a frequency reference, buy a cheap Rubidium unit off eBay, typically costing £30 to £60;

24V DC input

10MHz output

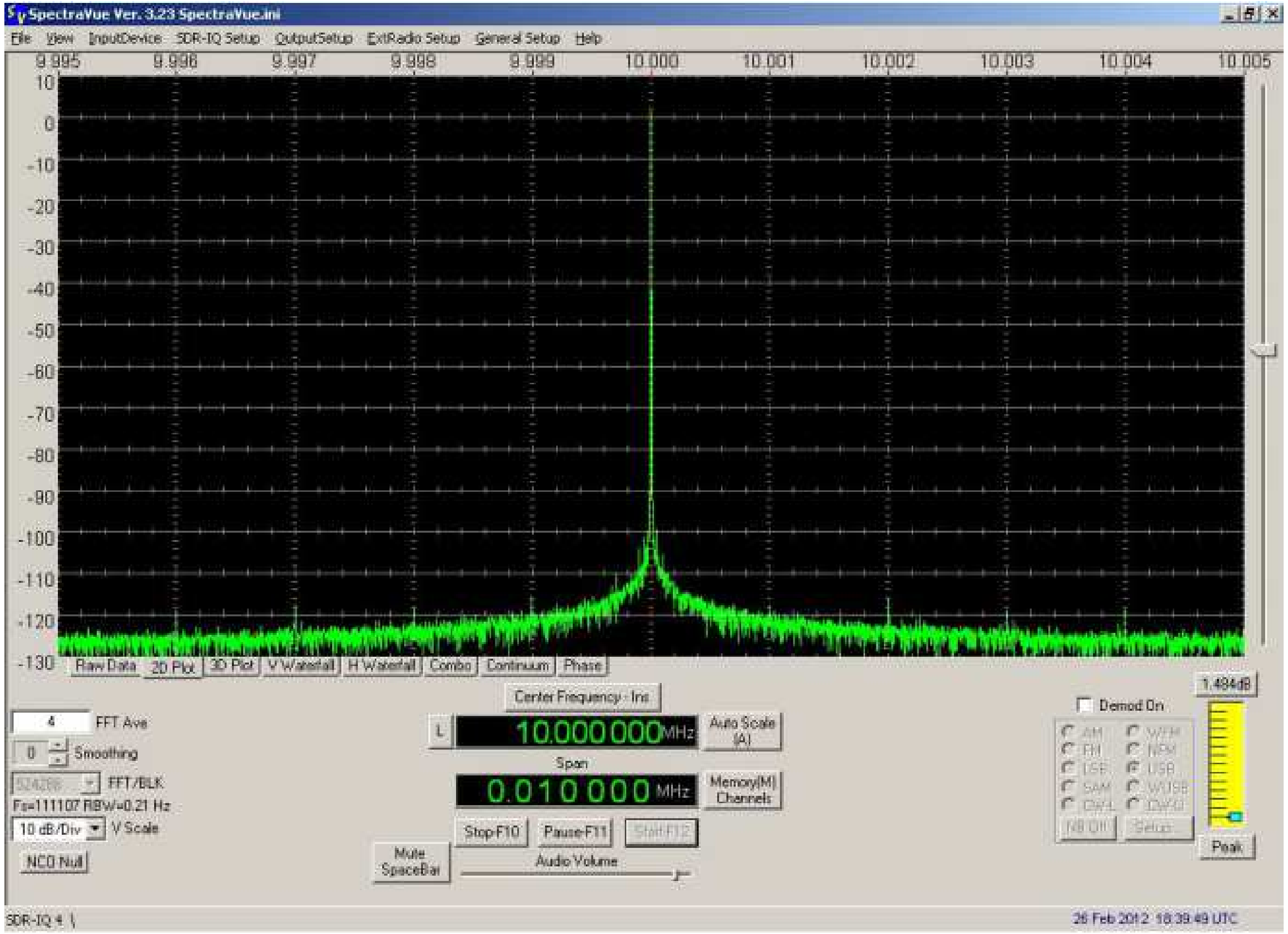
10 minutes to warm up



A man with one frequency standard knows what frequency it is.
A man with two frequency standards is never sure!

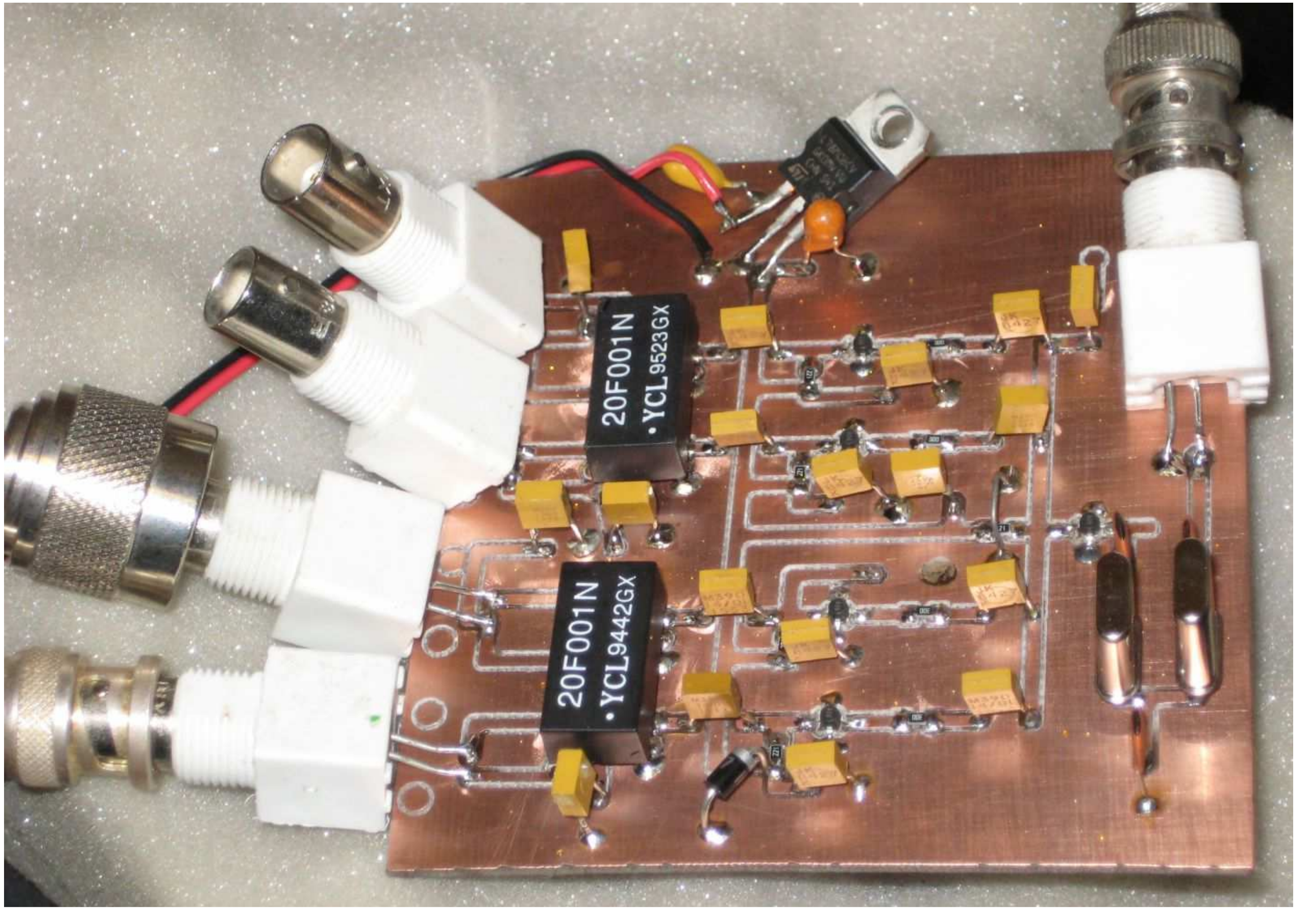
Frequency References

A cheap LPRO-101 Rubidium oscillator was measured, low level spurs exist but at about 110dB below the carrier – this is useable.



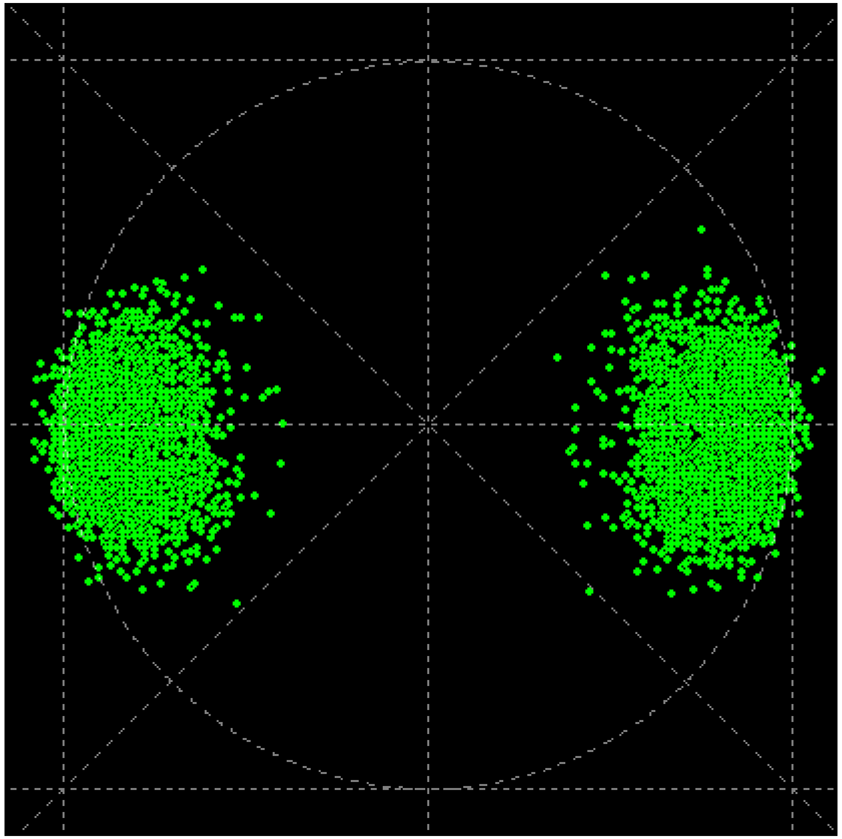
Frequency References

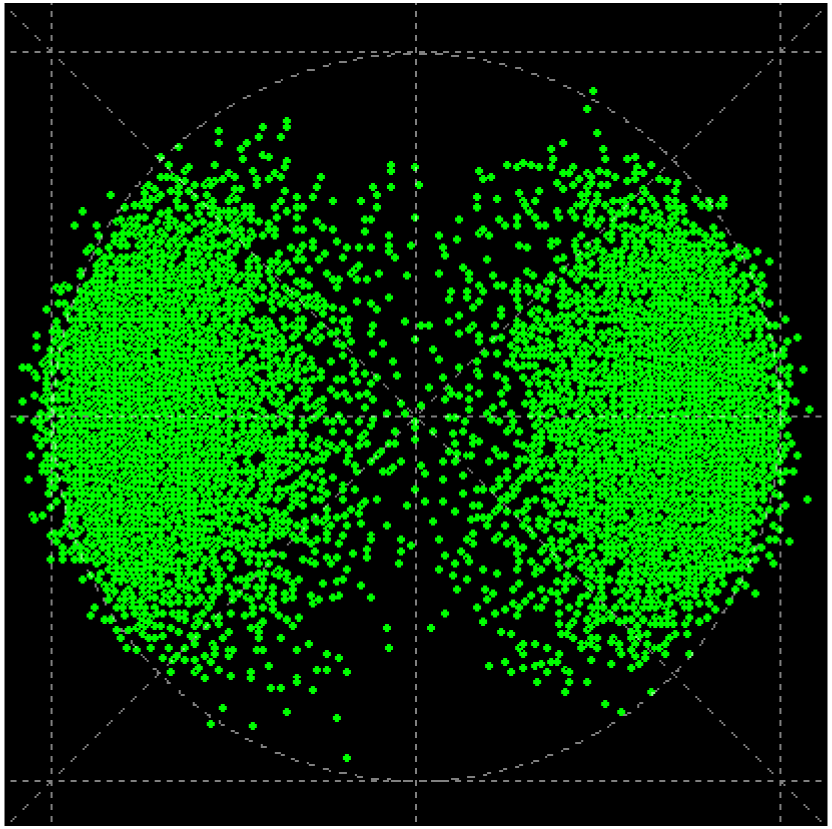
10MHz reference distribution can cause problems due to ground loops, a multi-port isolated amplifier is needed.



Frequency References

10MHz reference examples, left picture shows a clean 10MHz, right shows a 10MHz signal with ‘ground loop’ problem. Phase and coherence is almost totally destroyed !



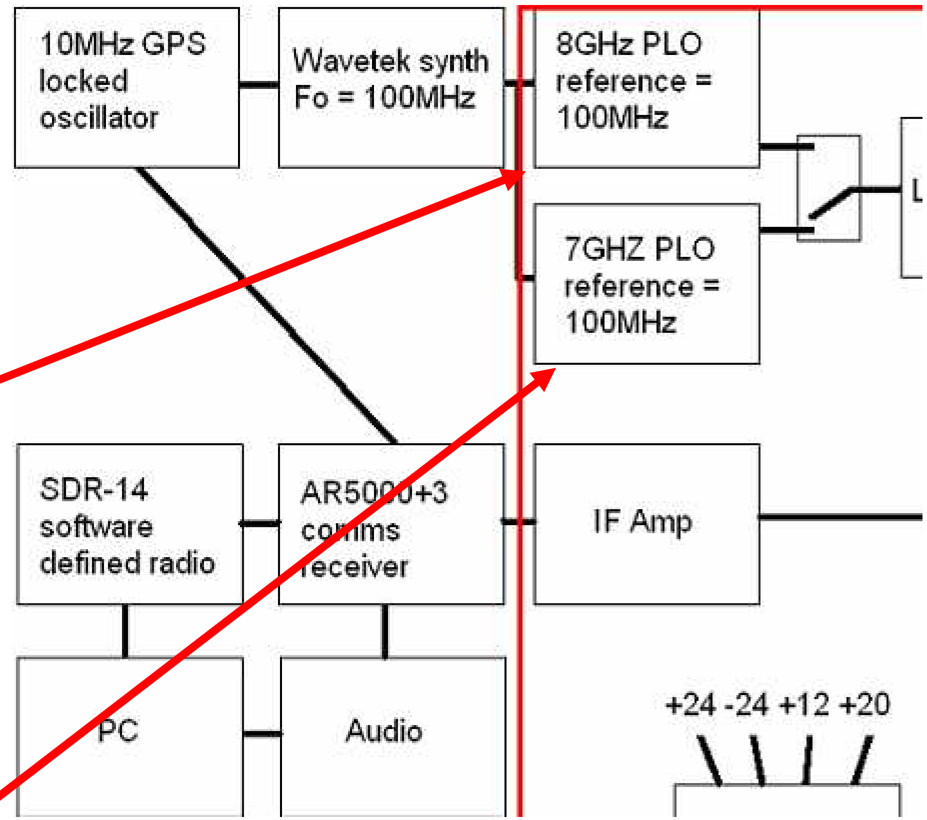


Frequency References

10MHz is distributed to a Wavetek synthesiser and a communications receiver.

The 8GHz LO is made by locking a 1·6GHz cavity oscillator to the 100MHz signal from the Wavetek. The 1·6GHz signal is then multiplied by 5 to generate 8 GHz.

A second PLO operates at 7GHz for 'testing' purposes.



Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX’d so far
- Future
- Questions

Receive Systems – DSN frequency bands

Most of the interesting deep space transmissions fall into one of the following bands;

Space to Earth.

S-Band – 2200MHz to 2300MHz (popular, also for LEO)
X-Band – 8·4GHz to 8·45GHz (popular)
X-Band – 12·75GHz to 13·25GHz (not used)
Ka-Band – 25·5GHz to 26·5GHz (close in ‘deep space’)
Ka-Band – 31·8GHz to 32·3GHz (starting to become popular)

X-Band – 8·4GHz to 8·45GHz is the ideal band to start with in DSN!
Your band of interest will dictate what you need in the way of equipment of course…

Receive Systems – Dish antennas

As far as dish size goes, the bigger the better!

Receive Systems – S-Band

S-Band systems are typically like those needed for AO-51; a dish, feed and suitable LNA for 2·2 to 2·3GHz. A BPF is also required.

Shown here is a 1m diameter 'WLAN' mesh antenna on an AZ/EL mount made from an old CCTV positioning head.

Excellent LNA's are available from the usual sources, DB6NT, SSB etc

This system uses a DDK VLNA, with a measured NF of 0·32dB and an associated gain of 25dB. A 3 turn LHCP helical antenna illuminates the dish correctly.

Receive Systems – Down Converters

What X-Band equipment is available ‘off the shelf’ ?

DB6NT equipment:
Regarded as the leader in amateur microwave communications equipment.

The DB6NT X-Band LNA costs ~200€ and the converter, around ~550€

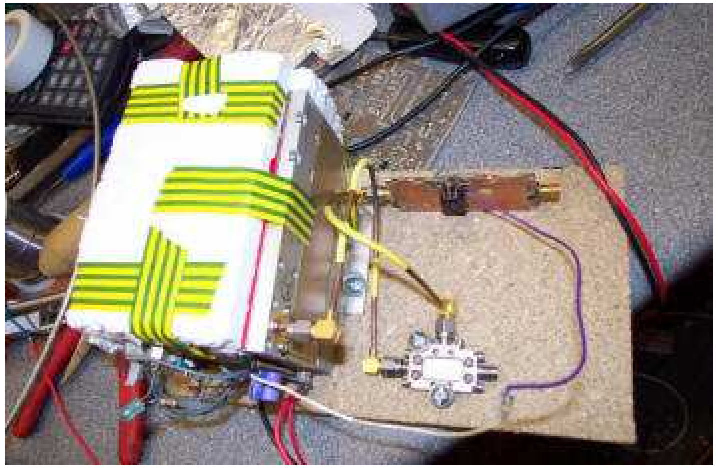
If you like playing microwaves, you can build your own down converter, LNA and feed horn!

There are no Ka-Band down-converters available off the shelf, within a typical ‘amateur’ budget.

Receive Systems – Down Converters

The M0EYT X-band converter : first test version (Q2 2004)

This is the very first version of the X-band down converter. LO is a MA/COM PLO with built in synthesiser – i.e. programmable but horrifically noisy



LNA is ex-Satcom and the dish feed is home built

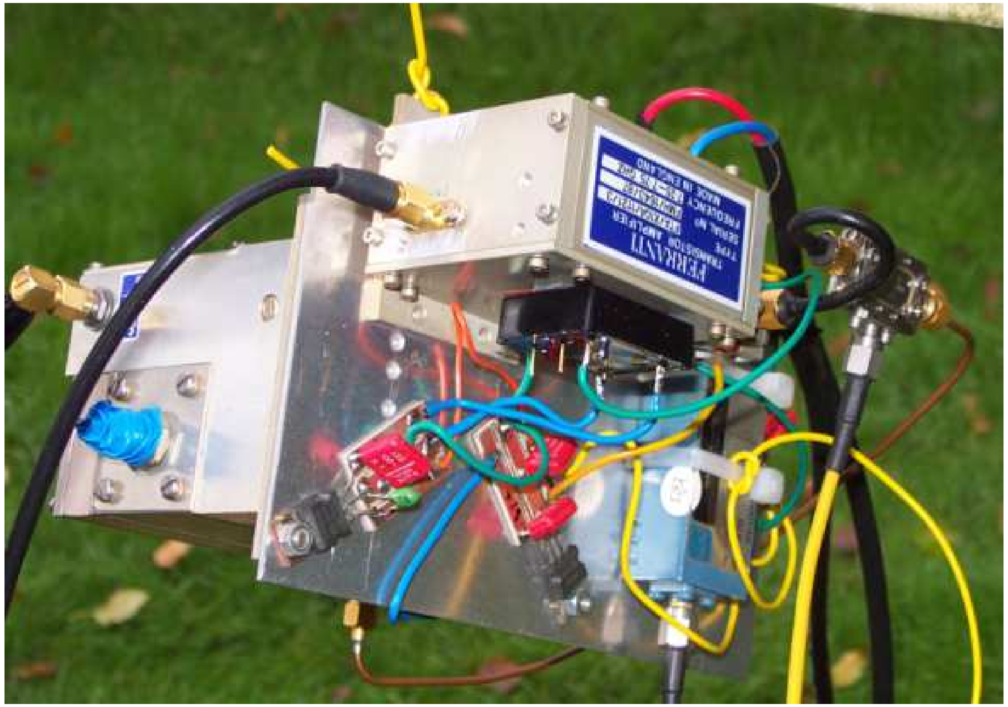
Signals were just about detectable from Geostationary X-Band satellites…

Most parts came from eBay !

Receive Systems – Down Converters

The M0EYT X-band converter : test version (Q4 2005)

The next version:



Phase locked oscillator with 100MHz external reference to generate an 8GHz LO

2 X Ferranti ex-Satcom LNA’s
Avantek IF amplifier
Miteq mixer

Image noise was an issue…

Receive Systems – Down Converters

The M0EYT X-band converter : test version (Q4 2005)

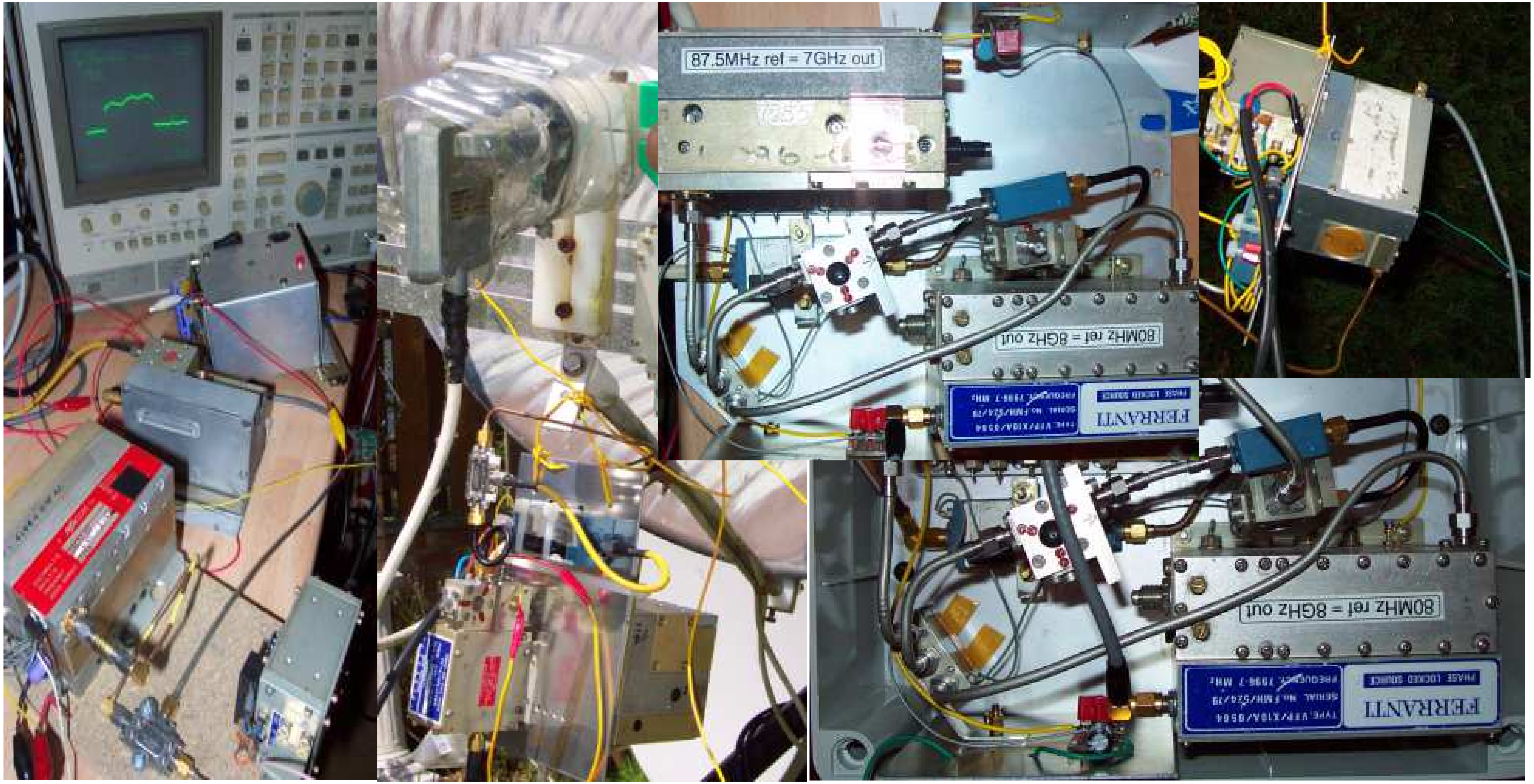
Image noise was a big problem - It results from the mixing product of RF and LO. i.e. LO=8GHz, RF = 8·4GHz resultant IF = 400 MHz but noise at 7·6GHz means the IF = 400 MHz too.

Solution: a home made iris coupled band pass filter in waveguide 16

The plot was taken during setup, and is not the final result!

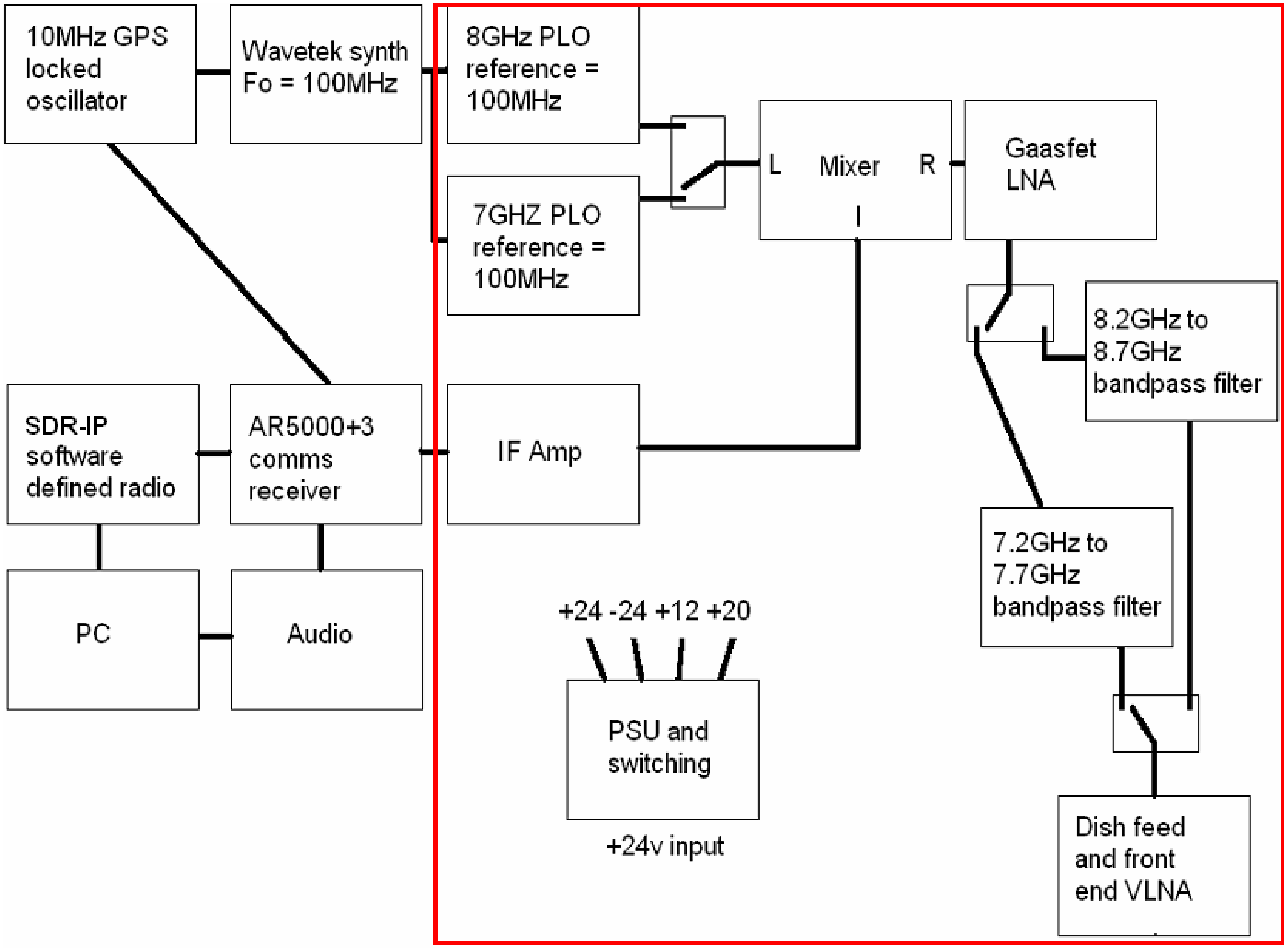
Receive Systems – Down Converters

The M0EYT X-band converter : ‘n’ intermediate versions…



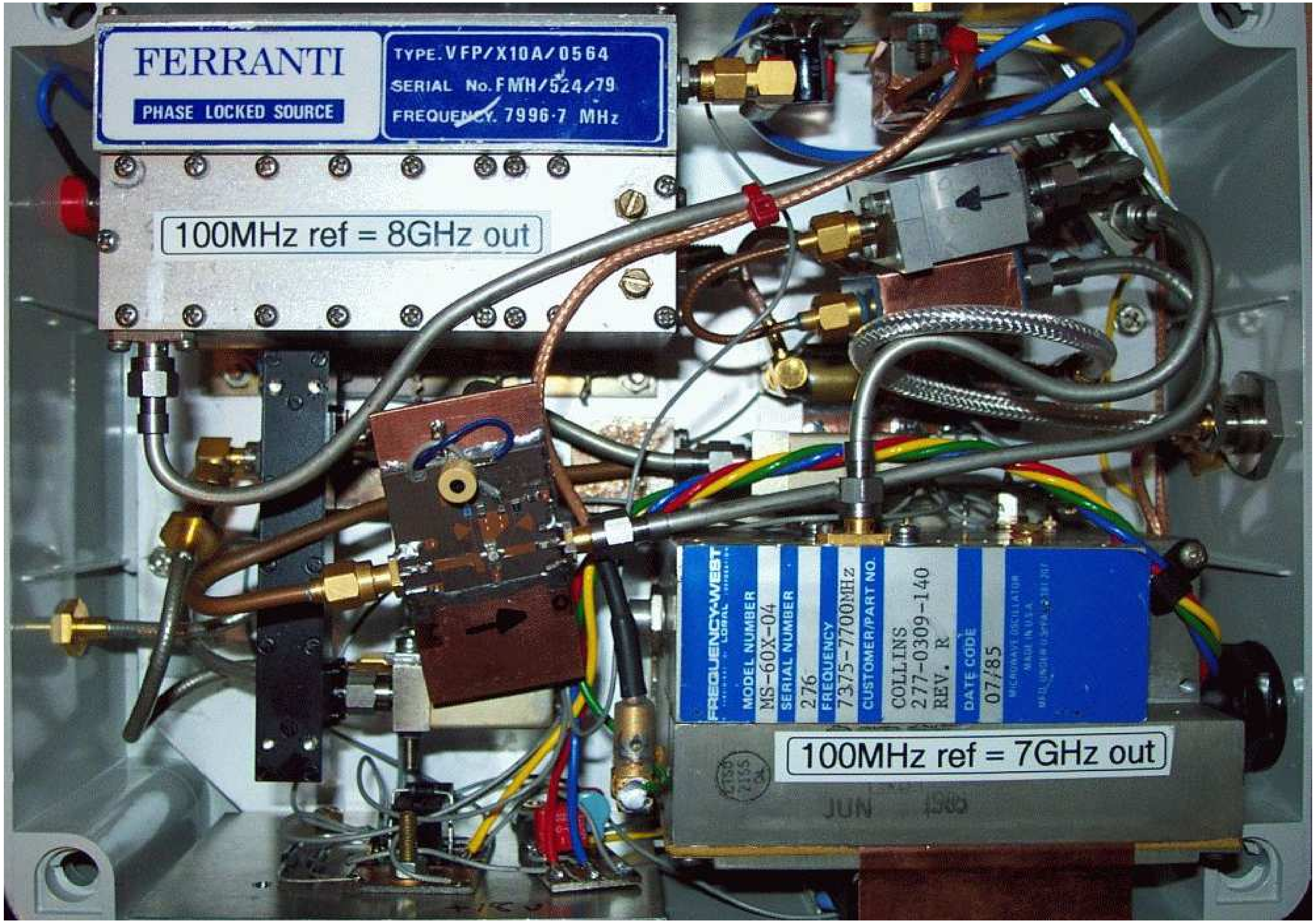
Receive Systems – Down Converters

The M0EYT X-Band down converter : “final” build block diagram

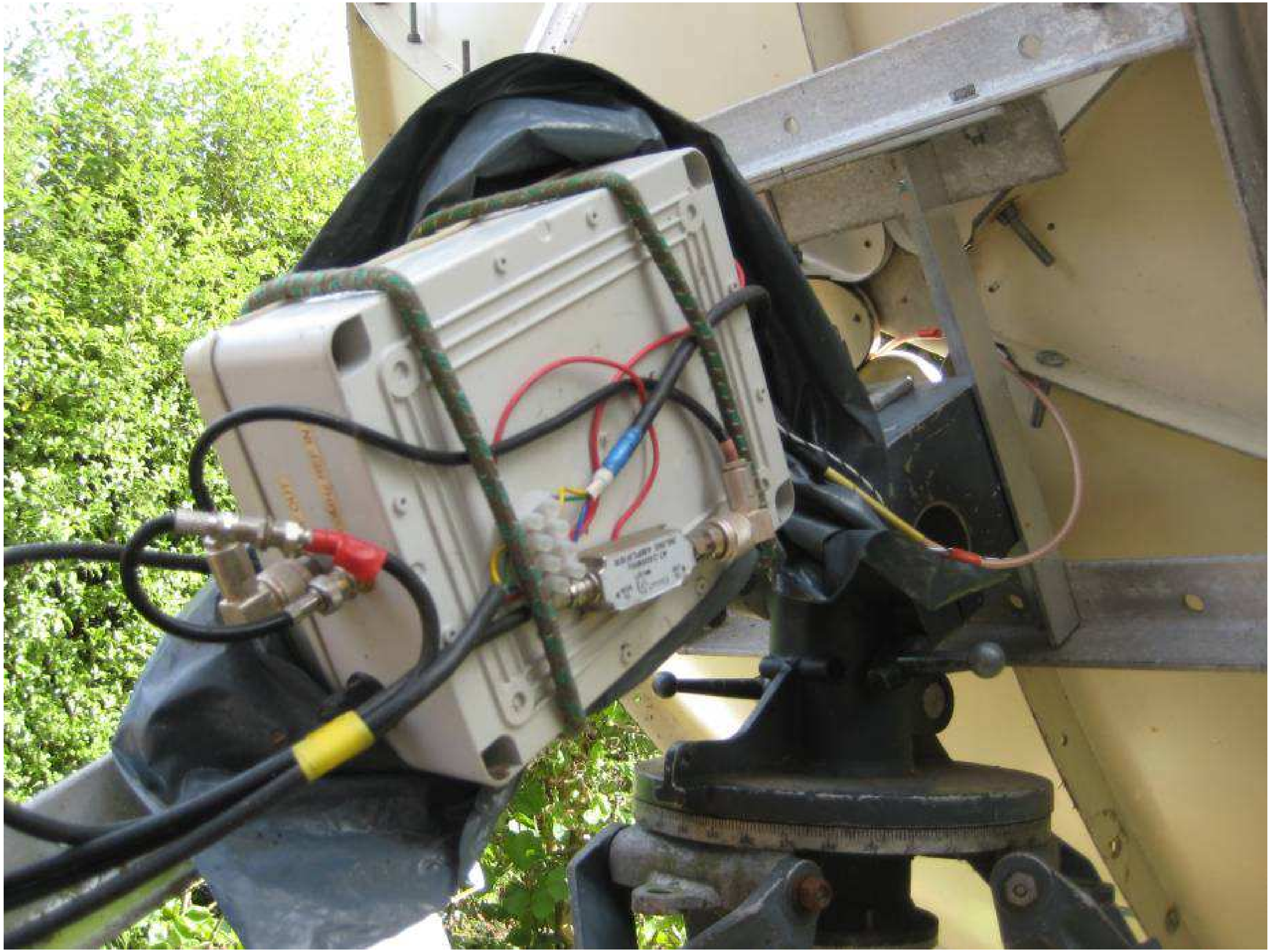


Receive Systems – Down Converters

Current dual X-Band down converter - Feb 2012

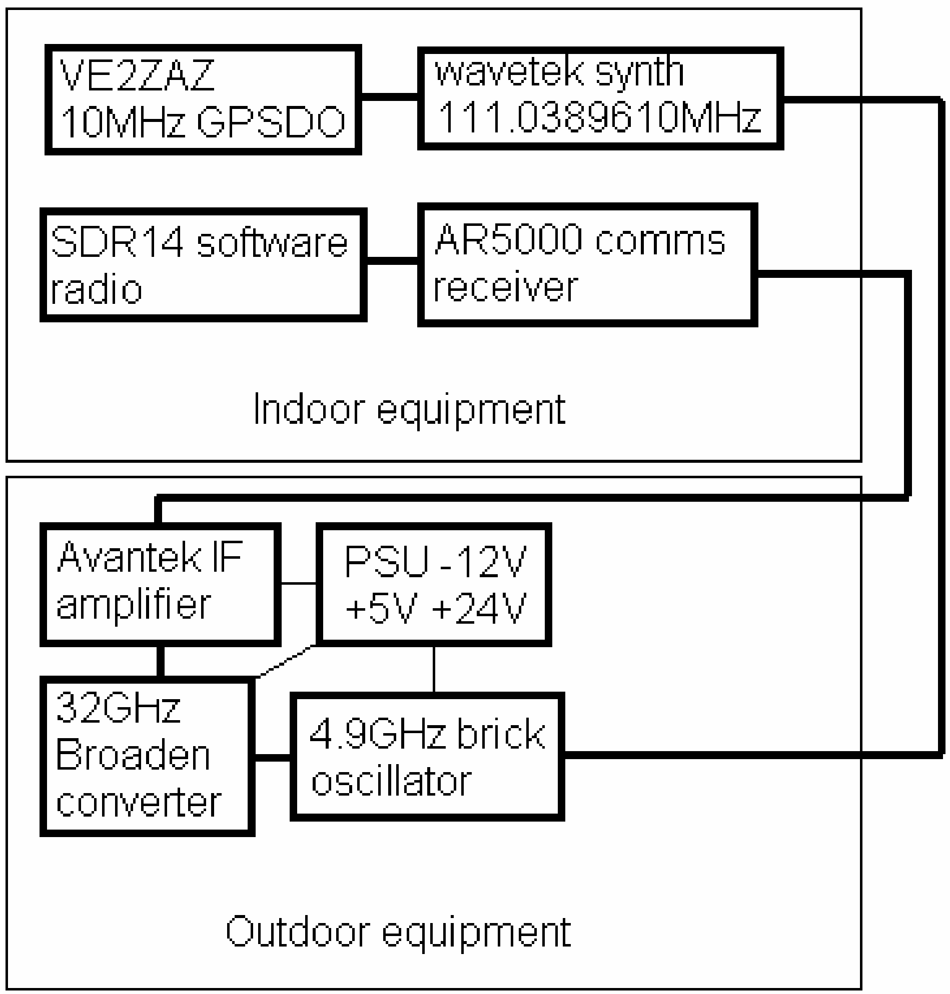


Receive Systems – Down Converters



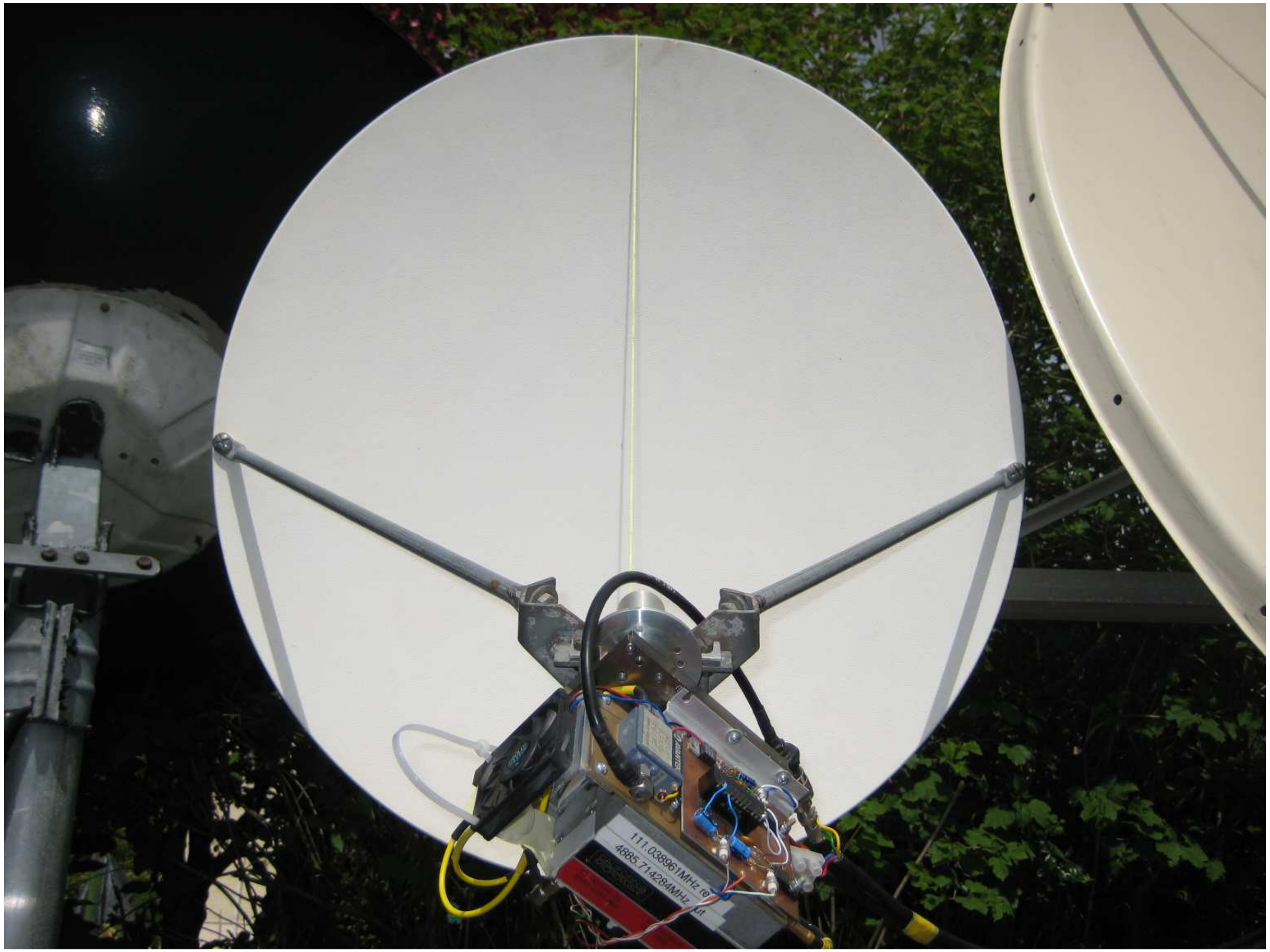
Receive Systems – Down Converters

Current Ka-Band down converter – March 2012



Receive Systems – Down Converters

Current Ka-Band down converter - March 2012. Shown here is the system for Kepler 32GHz downlink reception.

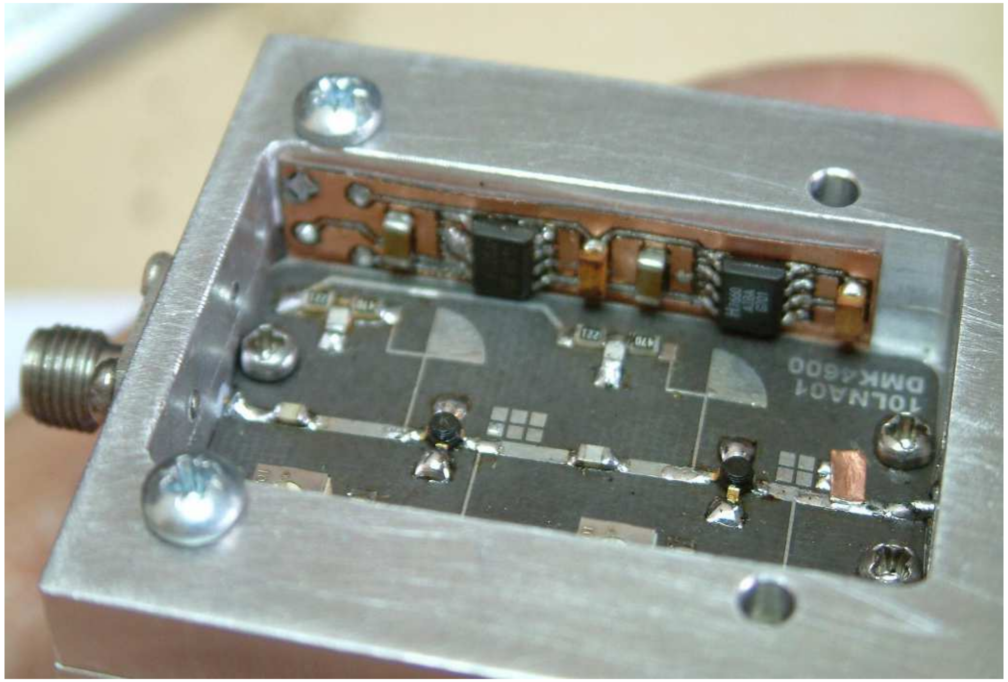


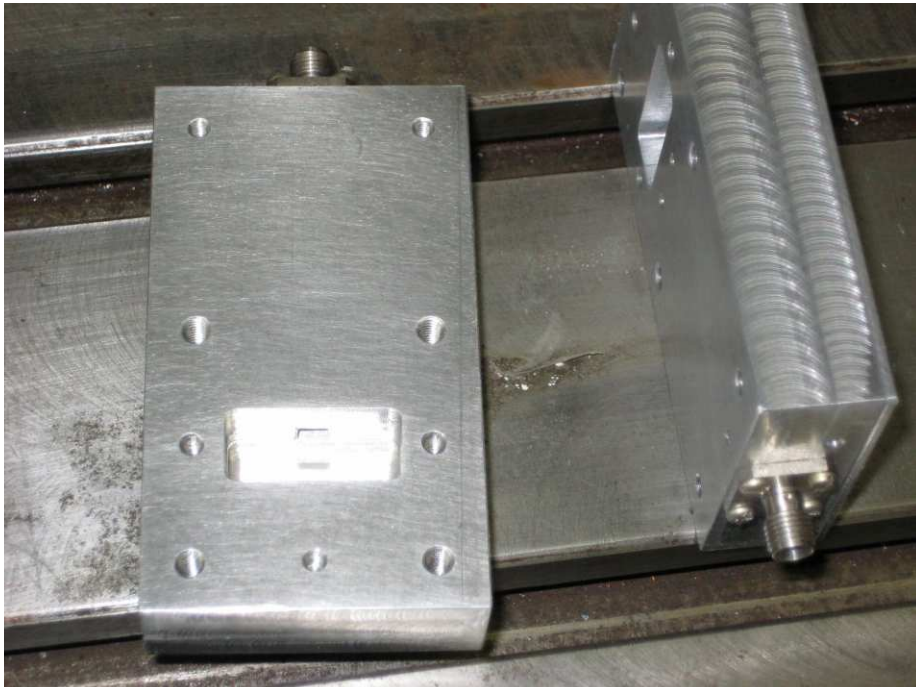
Receive Systems – LNA / Dish feed

The X Band dish feed and LNA also went through a few iterations:

Receive Systems – LNA / Dish feed

Current X band LNA assembly - March 2012
Based on CT1DMK design, with metalwork by Paul - M0EYT and board / NF optimisation by Iban - EB3FRN
NF = 0·6dB @ 8425MHz, Gain = 28dB. Front end FET NE3210S01

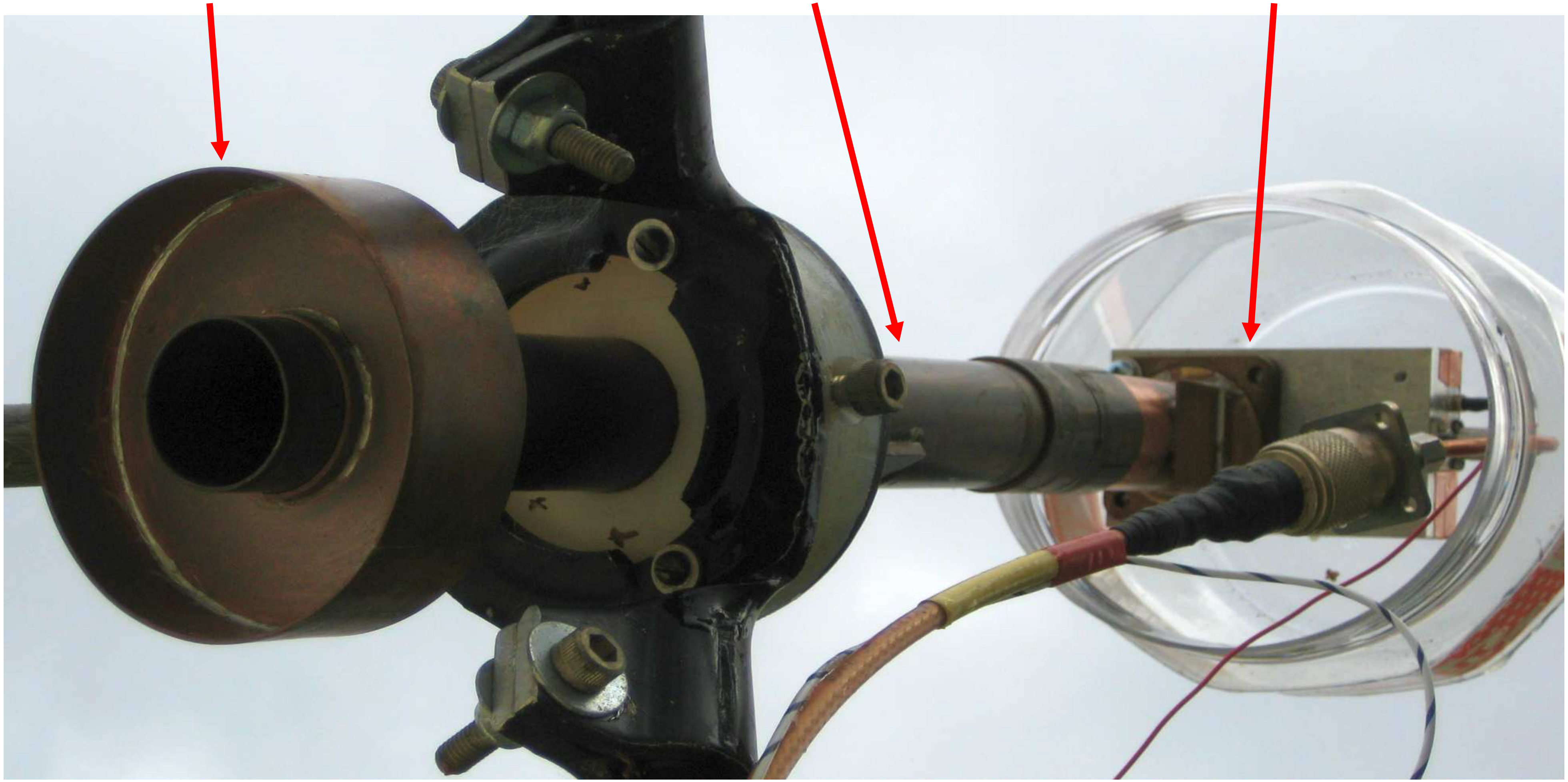




Receive Systems – LNA / Dish feed

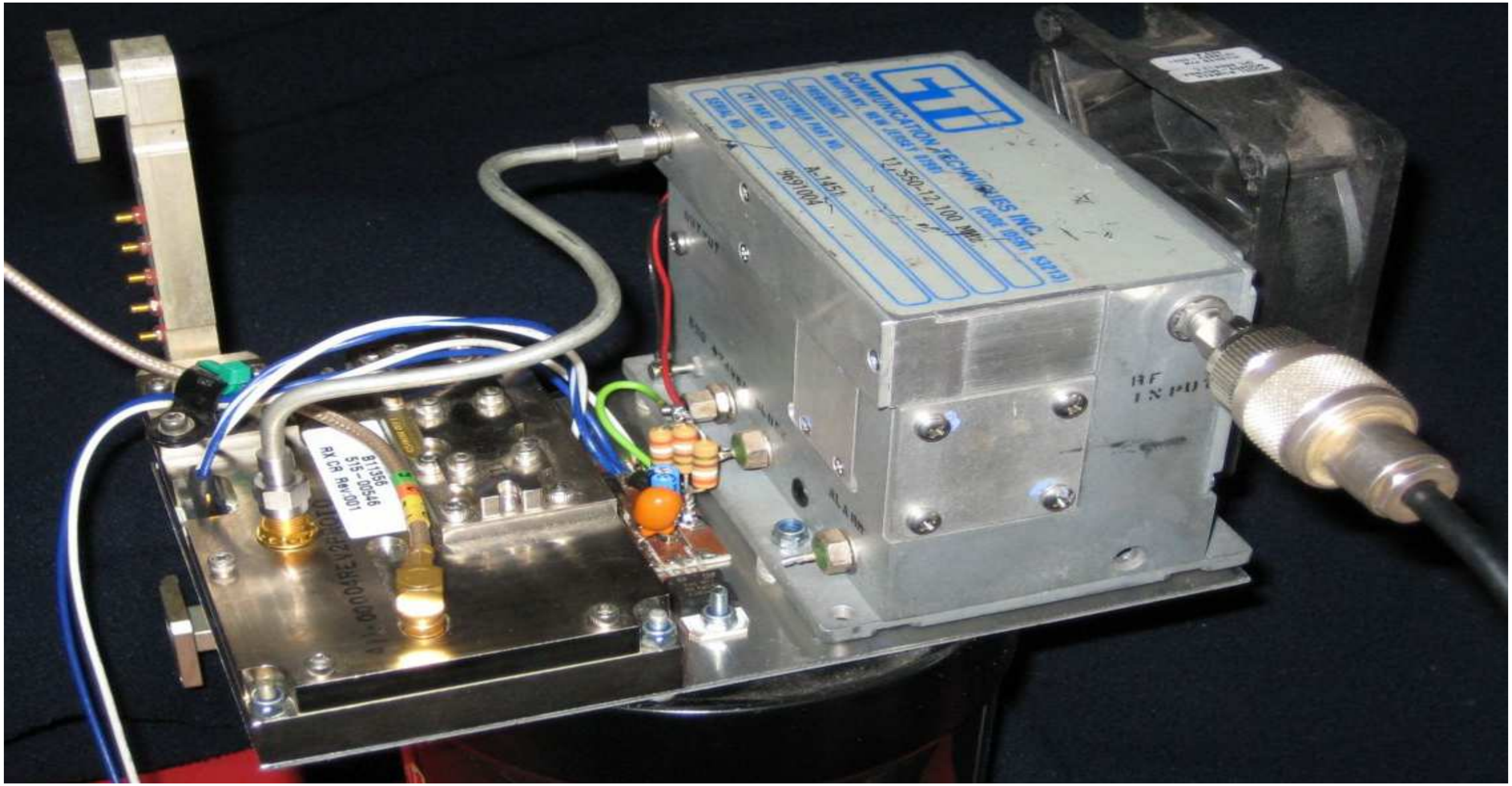
Current X band feed / LNA assembly - March 2012

Super VE4MA feed, Squeezed Pipe depolariser, EYT/FRN LNA



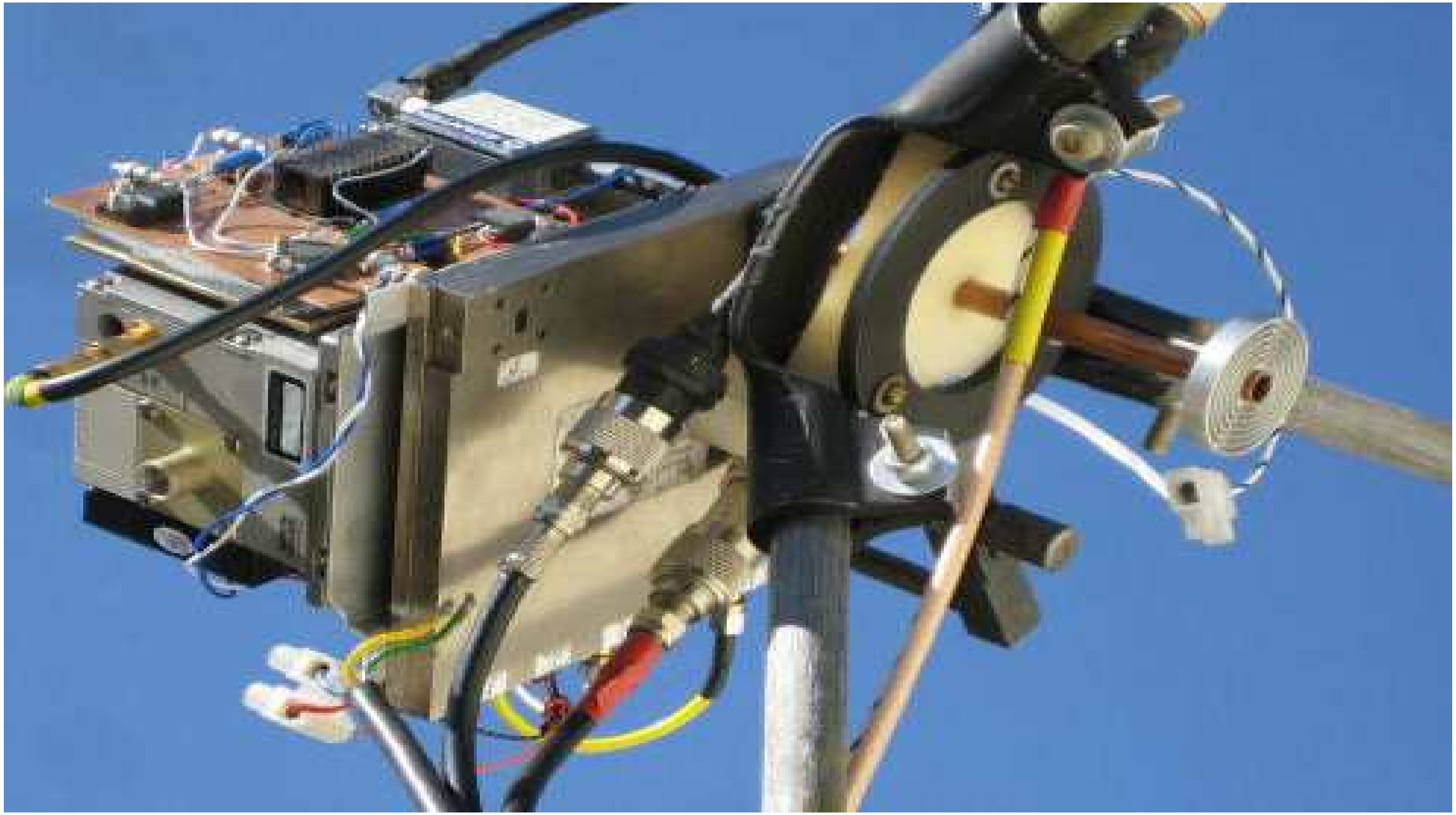
Receive Systems – Ka band

Higher frequency converters have also been built; this one is for the 25·65GHz downlink from NASA’s Lunar Reconnaissance Orbiter.



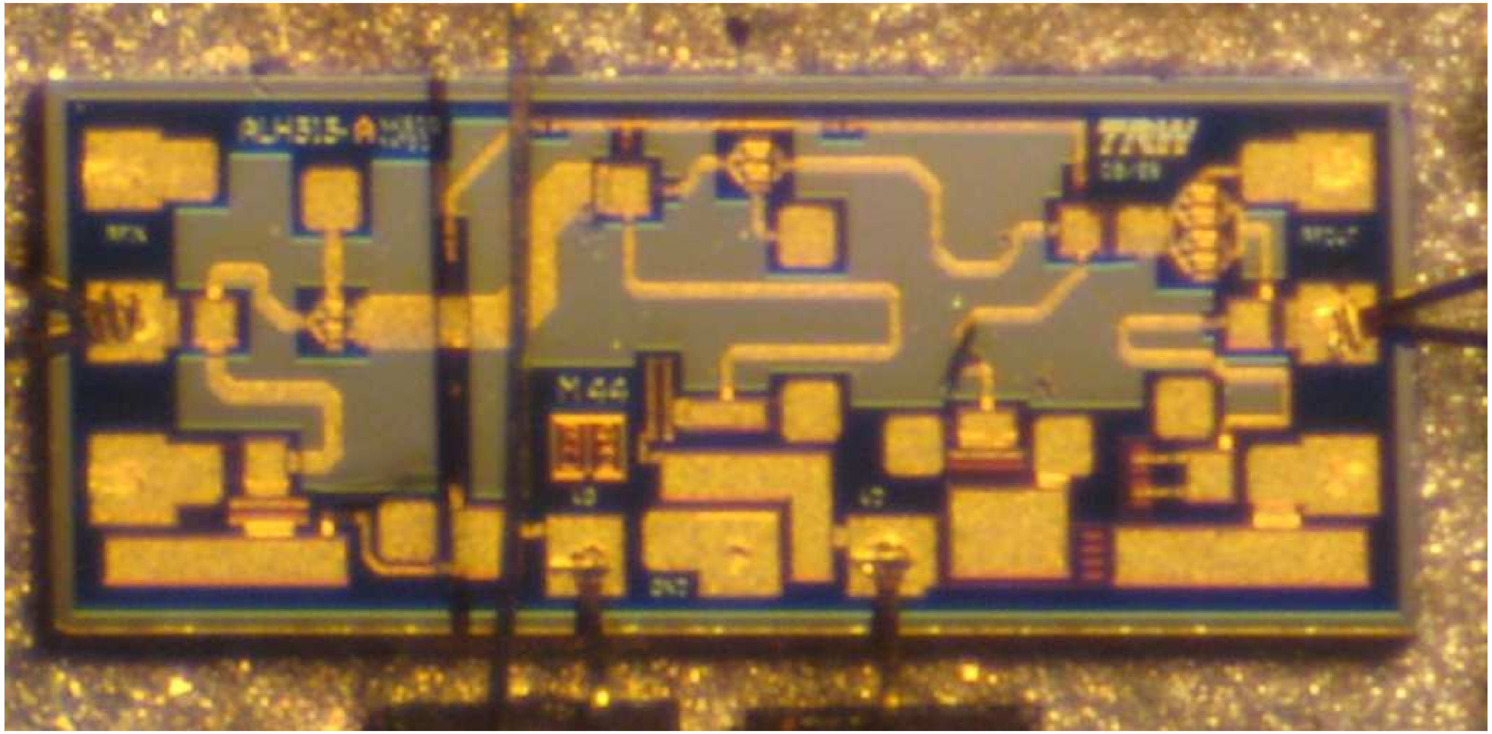
Receive Systems – Ka band

And this one is for the 32·166171GHz downlink from NASA's Kepler exo-planet detection mission.



Receive Systems – Ka band

This is the front-end LNA in the Ka-band system, a HMC-ALH313;



It is a GaAs HEMT MMIC low noise amplifier covering 27GHz to 33GHz, with a 3dB NF.

Its physical size is just 1.8mm X 0.83mm

Agenda

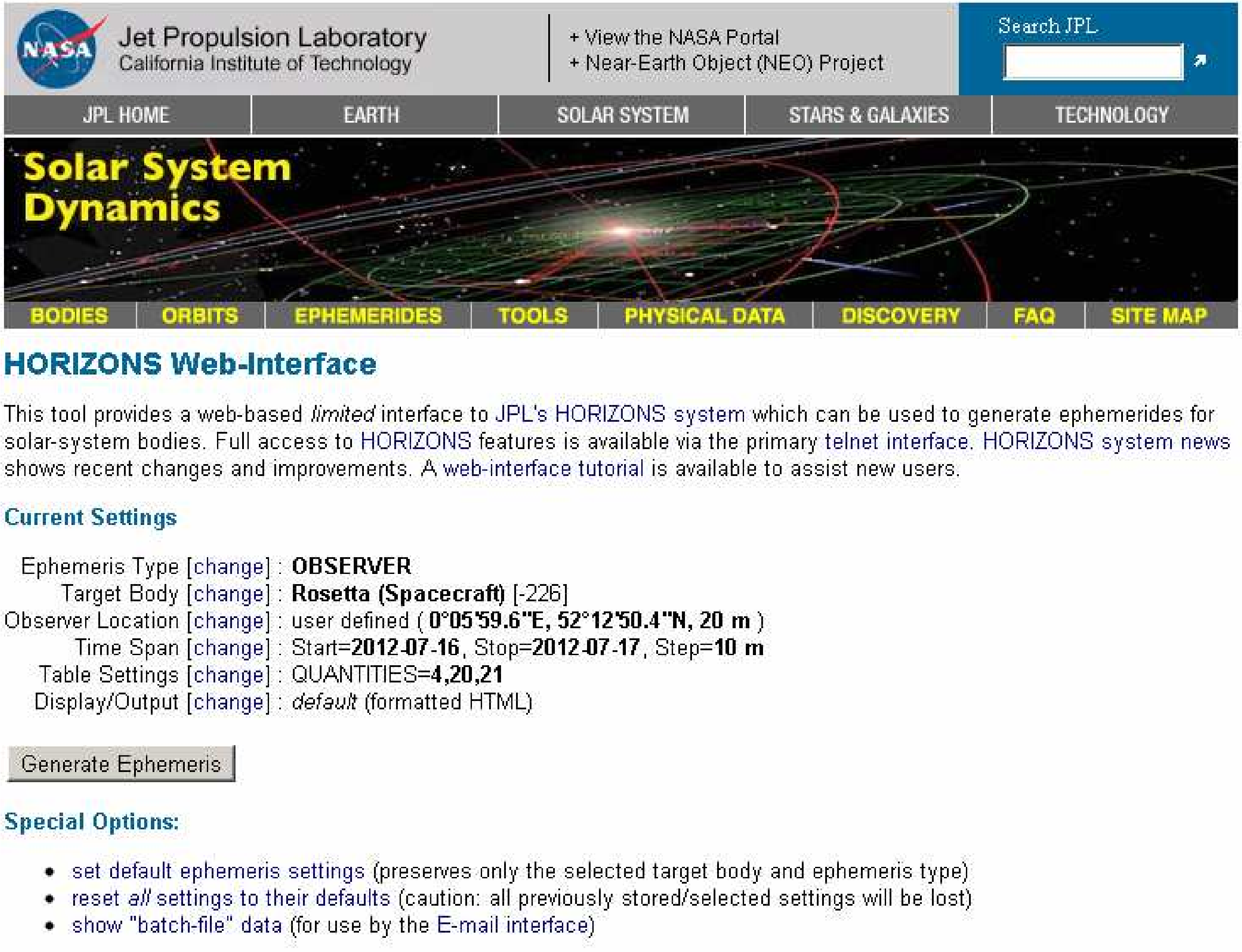
- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX’d so far
- Future
- Questions

Antenna Pointing

First get your location using GPS or Google Earth

Antenna Pointing

Enter data into JPL Horizons tool



Jet Propulsion Laboratory
California Institute of Technology

+ View the NASA Portal
+ Near-Earth Object (NEO) Project

Search JPL

JPL HOME | EARTH | SOLAR SYSTEM | STARS & GALAXIES | TECHNOLOGY

Solar System Dynamics

BODIES | ORBITS | EPHEMERIDES | TOOLS | PHYSICAL DATA | DISCOVERY | FAQ | SITE MAP

HORIZONS Web-Interface

This tool provides a web-based *limited* interface to JPL's HORIZONS system which can be used to generate ephemerides for solar-system bodies. Full access to HORIZONS features is available via the primary telnet interface. HORIZONS system news shows recent changes and improvements. A web-interface tutorial is available to assist new users.

Current Settings

Ephemeris Type [change] : **OBSERVER**
Target Body [change] : **Rosetta (Spacecraft)** [-226]
Observer Location [change] : user defined (**0°05'59.6"E, 52°12'50.4"N, 20 m**)
Time Span [change] : Start=**2012-07-16**, Stop=**2012-07-17**, Step=**10 m**
Table Settings [change] : QUANTITIES=**4,20,21**
Display/Output [change] : *default* (formatted HTML)

Generate Ephemeris

Special Options:

- set default ephemeris settings (preserves only the selected target body and ephemeris type)
- reset *all* settings to their defaults (caution: all previously stored/selected settings will be lost)
- show "batch-file" data (for use by the E-mail interface)

Antenna Pointing

Target body name: Rosetta (Spacecraft) (-226) {source: ROEM_100615OAS_PREDICT__}
Center body name: Earth (399) {source: DE405}
Center-site name: (user defined site below)

****

Start time : A.D. 2012-Jul-16 00:00:00.0000 UT
Stop time : A.D. 2012-Jul-17 00:00:00.0000 UT
Step-size : 10 minutes

****

Target pole/equ : No model available
Target radii : (unavailable)
Center geodetic : 0.09990000,52.2140463,0.0203150 {E-lon(deg),Lat(deg),Alt(km)}
Center cylindric: 0.09990000,3916.18155,5017.4440 {E-lon(deg),Dxy(km),Dz(km)}
Center pole/equ : High-precision EOP model {East-longitude +}
Center radii : 6378.1 x 6378.1 x 6356.8 km {Equator, meridian, pole}
Target primary : Earth {source: DE405+DE406}
Interfering body: MOON (Req= 1737.400) km {source: DE405}
Deflecting body : Sun, EARTH {source: DE405}
Deflecting GMs : 1.3271E+11, 3.9860E+05 km^3/s^2
Atmos refraction: NO (AIRLESS)
RA format : HMS
Time format : CAL
RTS-only print : NO
EOP file : eop.120713.p121004
EOP coverage : DATA-BASED 1962-JAN-20 TO 2012-JUL-13. PREDICTS-> 2012-OCT-03
Units conversion: 1 AU= 149597870.691 km, c= 299792.458 km/s, 1 day= 86400.0 s
Table cut-offs 1: Elevation (-90.0deg=NO),Airmass (>38.000=NO), Daylight (NO)
Table cut-offs 2: Solar Elongation (0.0,180.0=NO)

****

Date(UT)HR:MN		Azi	Elev	delta	deldot KM/s	1-way_LT m
2012-Jul-16 19:20	*	173.1839	15.9711	4.68179437400684	24.8826581	38.937296
2012-Jul-16 19:30	*	175.6052	16.1212	4.68189419884528	24.8959024	38.938127
2012-Jul-16 19:40	*	178.0314	16.2066	4.68199407689078	24.9091866	38.938957
2012-Jul-16 19:50	*t	180.4598	16.2269	4.68209400825859	24.9224883	38.939788
2012-Jul-16 20:00	*	182.8876	16.1821	4.68219399297474	24.9357855	38.940620
2012-Jul-16 20:10	*	185.3123	16.0724	4.68229403097610	24.9490557	38.941452
2012-Jul-16 20:20	C	187.7311	15.8980	4.68239412211033	24.9622769	38.942284
2012-Jul-16 20:30	C	190.1415	15.6595	4.68249426613629	24.9754270	38.943117
2012-Jul-16 20:40	C	192.5411	15.3575	4.68259446272447	24.9884839	38.943951

Antenna Pointing

Determining the frequency to tune - the DSN tracking spreadsheet

03/10/2010 09:25		3	**8400.061729**	0.000000	8400.061729	0.000000				
Mars Science Lab - Autumn 2011 launch	Y	4	**8401.419752**	0.000000	8401.419752	0.000000			01/08/2007	
		4	**8401.577700**	5.591712	8401.420994	-156.705747				
Phoenix Lander MISSION ENDED	Y	5	**8402.777700**	5.543651	8402.622319	-155.381053	8402.614319			Y
		6	**8403.977700**	5.624661	8403.820026	-157.674165			01/08/2007	
NASA JUNO Jupiter mission (Aug 2011 launch)	Y	6	**8404.135802**	0.000000	8404.135802	0.000000				
NASA JUNO Jupiter mission (Aug 2011 launch)			**32085.930000**	0.000000	32085.930000	0.000000	2114.070000	100.268531		
		7	**8405.493825**	0.000000	8405.493825	0.000000				
Mars Odyssey -53 (Mars 499)	Y	8	**8406.851853**	15.079701	8406.428984	-422.868587			07/04/2001	Y
Hayabasu -130 / Ulysees -55 / Muses-C	Y	9	**8408.209877**	-4.664834	8408.340711	130.833517	8408.339711		09/05/2003	N
		10	**8409.567903**	0.000000	8409.567903	0.000000				
Planet-C / Pioneer -24 / -23		11	**8410.925927**	4.261643	8410.806363	-119.563913				
Pioneer -24 / -23		12	**8412.283950**	0.000000	8412.283950	0.000000				
Spitzer space telescope -79	Y	13	**8413.626490**	-0.532682	8413.641440	14.949631			25/08/2003	Y
		13	**8413.641977**	0.000000	8413.641977	0.000000				
Voyager -31-32 / Stardust -29	Y	14	**8415.000000**	18.851122	8414.470860	-529.140043				N
		15	**8416.358023**	0.000000	8416.358023	0.000000				
		16	**8417.716050**	0.000000	8417.716050	0.000000				
Venus Exp -248 (Venus 299)	Y	17	**8419.074073**	-4.899994	8419.211680	137.606580	8419.216680	add 5KHz	09/11/2005	Y
Mars Exp -41 (Mars 499) / Voyager -31 -32	Y	18	**8420.432097**	15.079701	8420.008545	-423.551680	8419.931545	doppler adjust	02/06/2003	Y
Rosetta -226	Y	19	**8421.790123**	23.298654	8421.135616	-654.507365	8421.132616	corrected freq	02/03/2004	Y
			2296.851000	23.298654	2296.672498	-178.501942				
		20	**8423.148147**	0.000000	8423.148147	0.000000				
MGS (Mars 499) MISSION ENDED	Y	20	**8423.177000**	-4.924350	8423.315358	138.357942			07/11/1996	Y
Kepler http://kepler.nasa.gov/	Y	21	**8424.506100**	1.200508	8424.472364	-33.735617				Y
Kepler http://kepler.nasa.gov/	Y		**32166.290000**	1.200508	32166.161191	-128.808696	2033.838809	100.519254		Y
		22	**8425.681100**	0.000000	8425.681100	0.000000	2033.833809		01/10/2008	
Magellan		22	**8425.864198**	0.000000	8425.864198	0.000000				N
Mars Pathfinder / Cassini		23	**8427.222221**	10.393449	8426.930059	-292.161806				N

Live document online at http://www.uhf-satcom.com/DSN.xls

Detecting signals – Antenna Pointing

Date(UT)HR:MN	Azi	Elev	delta	deldot KM/s	1-way_LT m
2012-Jul-16 19:20 *	173.1839	15.9711	4.68179437400684	24.8826581	38.937296
2012-Jul-16 19:30 *	175.6052	16.1212	4.68189419884528	24.8959024	38.938127
2012-Jul-16 19:40 *	178.0314	16.2066	4.68199407689078	24.9091866	38.938957
2012-Jul-16 19:50 *t	180.4598	16.2269	4.68209400825859	24.9224883	38.939788
2012-Jul-16 20:00 *	182.8876	16.1821	4.68219399297474	24.9357855	38.940620
2012-Jul-16 20:10 *	185.3123	16.0724	4.68229403097610	24.9490557	38.941452
2012-Jul-16 20:20 C	187.7311	15.8980	4.68239412211033	24.9622769	38.942284
2012-Jul-16 20:30 C	190.1415	15.6595	4.68249426613629	24.9754270	38.943117
2012-Jul-16 20:40 C	192.5411	15.3575	4.68259446272447	24.9884839	38.943951

Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX’d so far
- Future
- Questions

Detecting signals – Doppler Shift

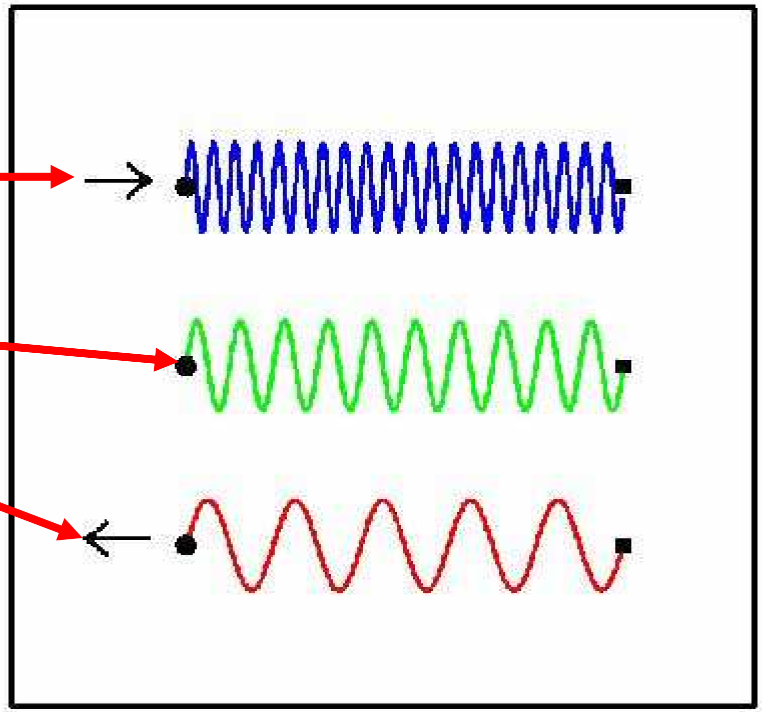
You cannot just randomly tune and find a signal from deep space. Several technical issues have to be addressed first:

- Somehow find the space craft transmitter frequency
- Determine the direction of the space craft for antenna pointing
- Factor in the Doppler shift caused by the relative motion

Space craft approaching

Nominal frequency

Space craft moving away



Detecting signals – Receivers

A communications RX is needed to cover S-Band 2·2GHz and the down converted UHF IF. Typically the RX will also need to be locked to the frequency reference, and have a suitable IF output for connection to the SDR. The AR5000(a) shown here satisfies these requirements.

Typically it covers from 5KHz to 3GHz and has an external 10.7MHz IF output, along with an input for a 10MHz ref.

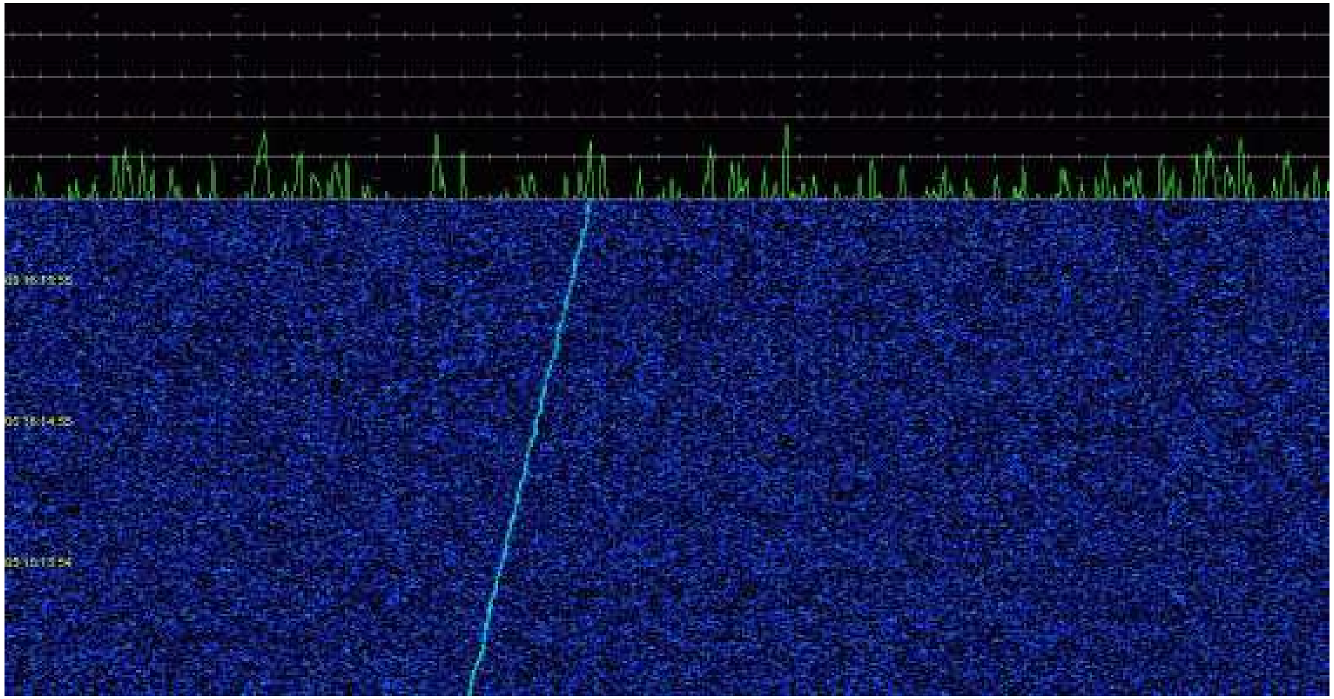
Detecting signals – SDR

Following those steps, we now have the parameters required to potentially receive the signal,

BUT

How do you tune the signal in if you cannot hear it;

Answer: FFT and SDR



Detecting signals – SDR

FFT'ing the audio is ok if the signal is in the RX pass band…

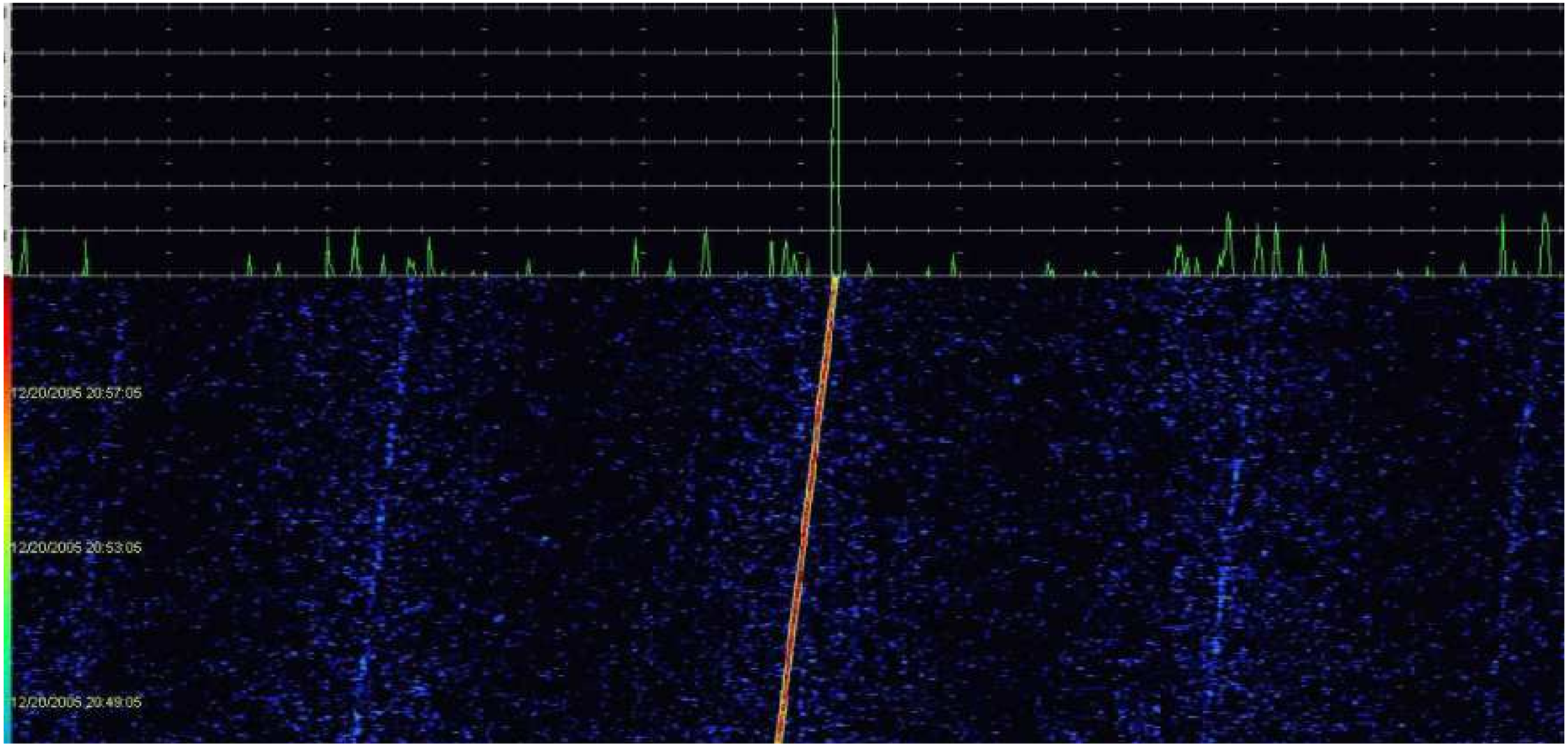
Doppler and tweaks in frequency at the spacecraft can mean you could miss the signal completely – solution: a SDR

The SDR-IP can 'look' at 2MHz of real-time RF at once – practical bandwidth to increase FFT resolution is 200 to 500 KHz. The SDR looks at the 10·7MHz IF output of an AR5000 receiver. SDR's really help when looking for space craft with high rates of Doppler.

Detecting signals – SDR

The result with the SDR looking at 250KHz of RF:

An easy copy of the MRO tracking beacon at 53,248,299 miles



Detecting signals – SDR

SDR and FFT visualisation have significant processing advantages;

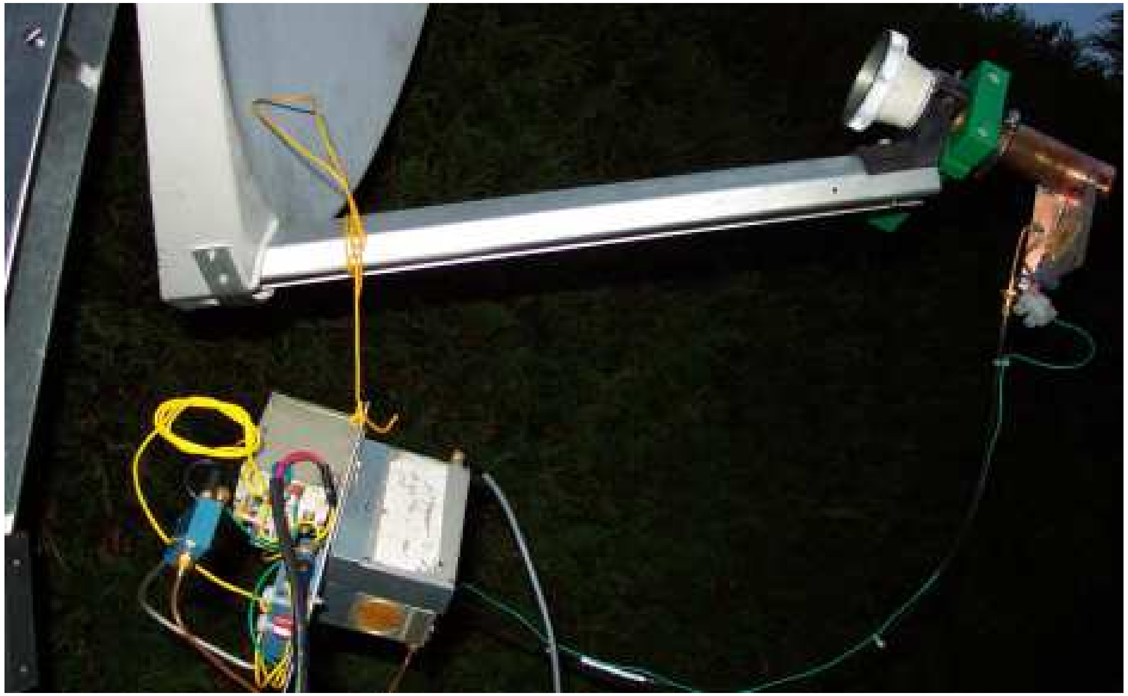
- Coherent signals are generally easier to see in FFT than to detect by ear
- Averaging can be performed to bring coherent signals out of the noise
- NCO stepping to counteract Doppler shift allows for signal energy to remain in a single FFT ‘bin’
- For best results the SDR should have its internal sample clock locked to an external reference

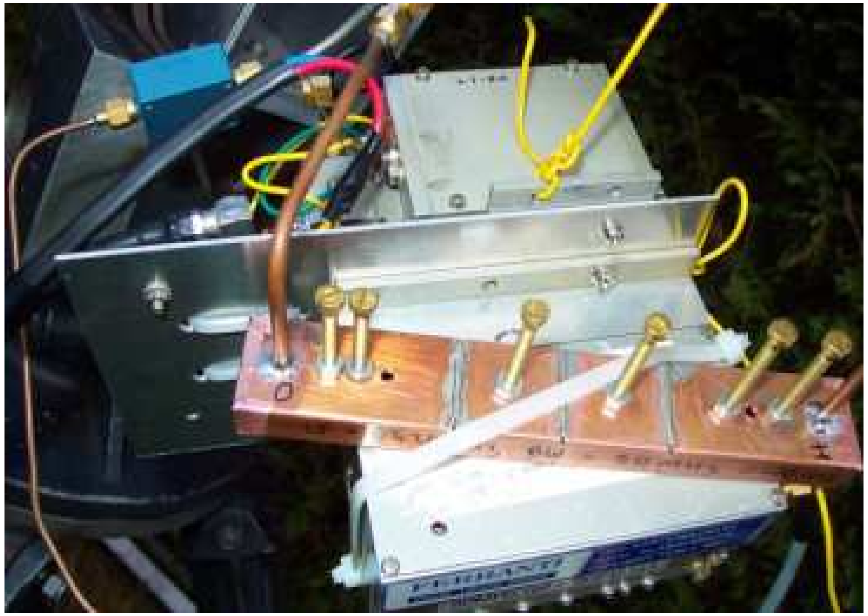
Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX'd so far
- Future
- Questions

First signals at the M0EYT Earth Station

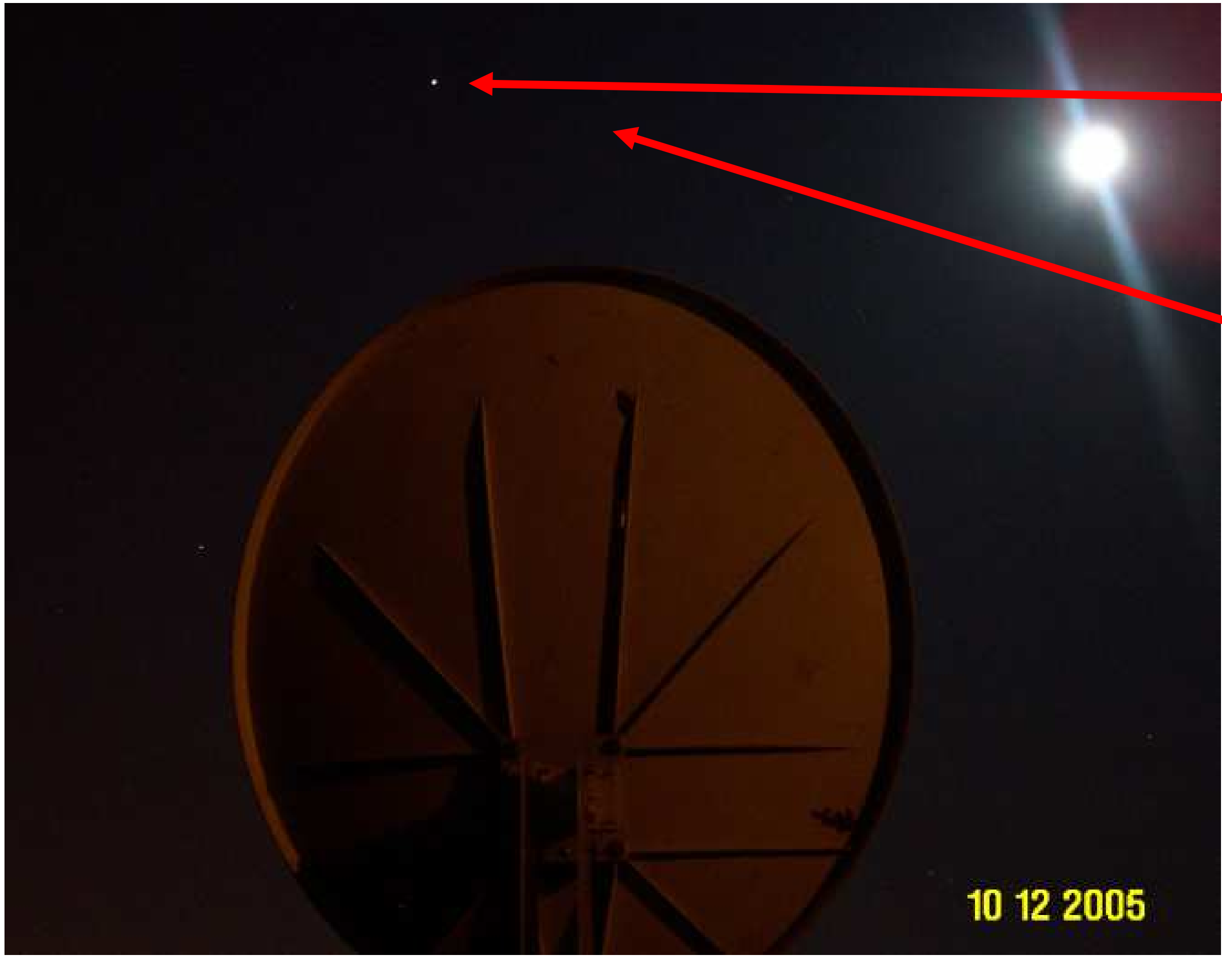
The first DSN signal copied at the M0EYT Earth Station was from the Venus Express spacecraft launched 9th November 2005.
Signals were received on the 5th of December 2005 at 15:50UTC with the spacecraft only 4,032,732 miles away!
As can be seen, the equipment was a lash up…





First signals at the M0EYT Earth Station

After Venus Express, the Mars Reconnaissance Orbiter was the next target at 45,151,194 miles from Earth

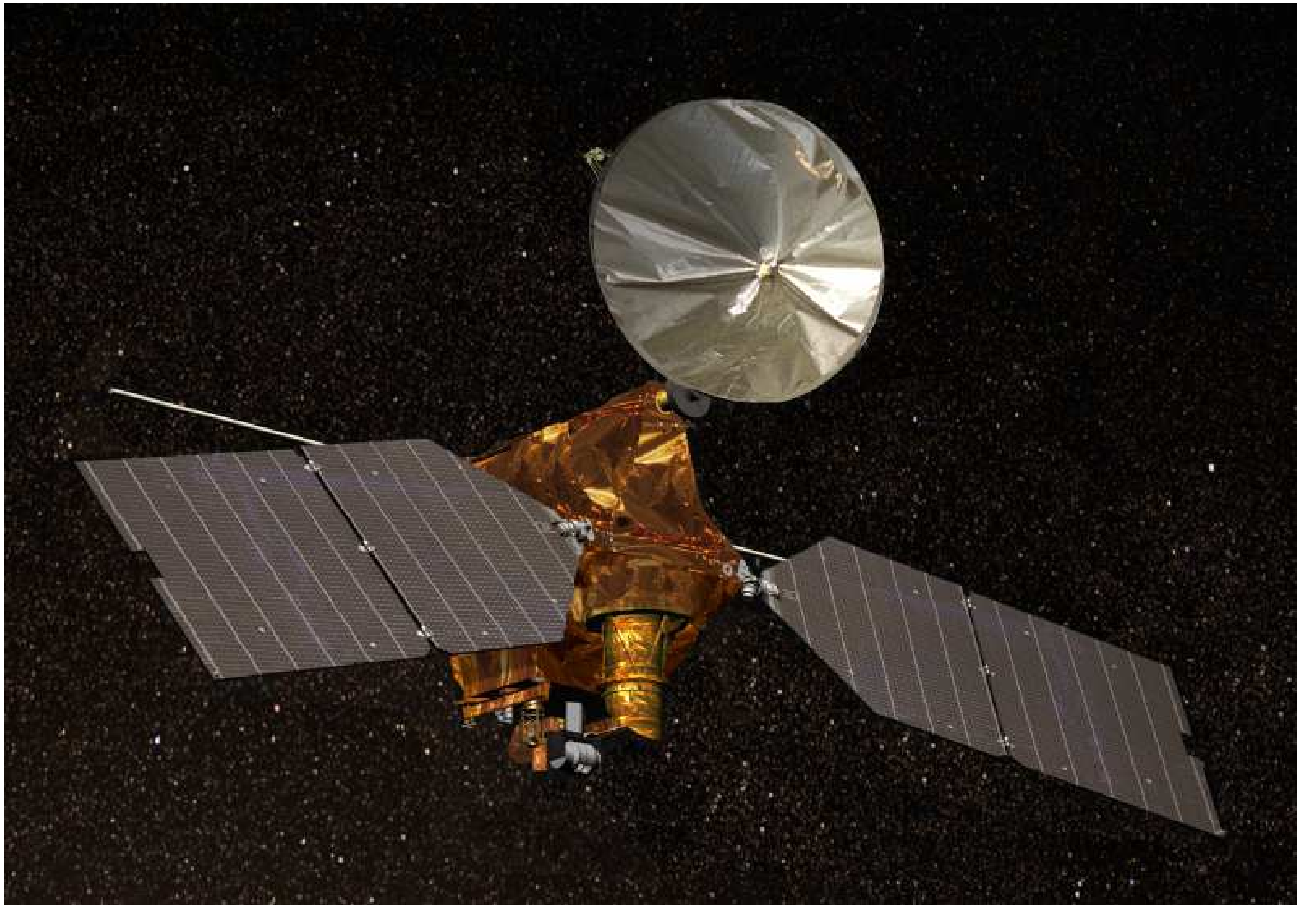


Mars

MRO is about here

First signals at the M0EYT Earth Station

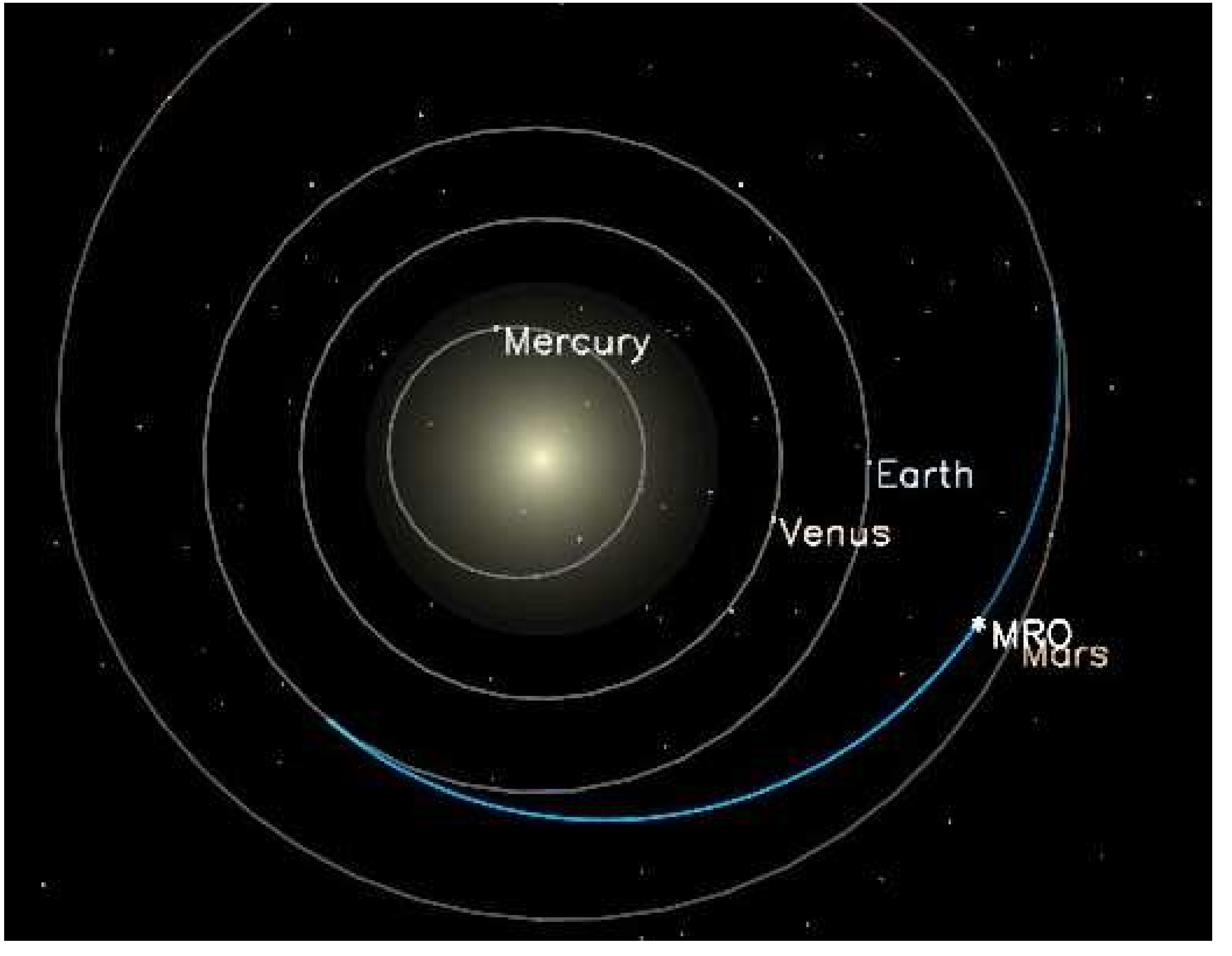
MRO was launched on the 12th of August 2005 from Cape Canaveral Air Force Station in the USA. MRO runs 100 watts to a 3m dish.



Courtesy NASA/JPL-Caltech

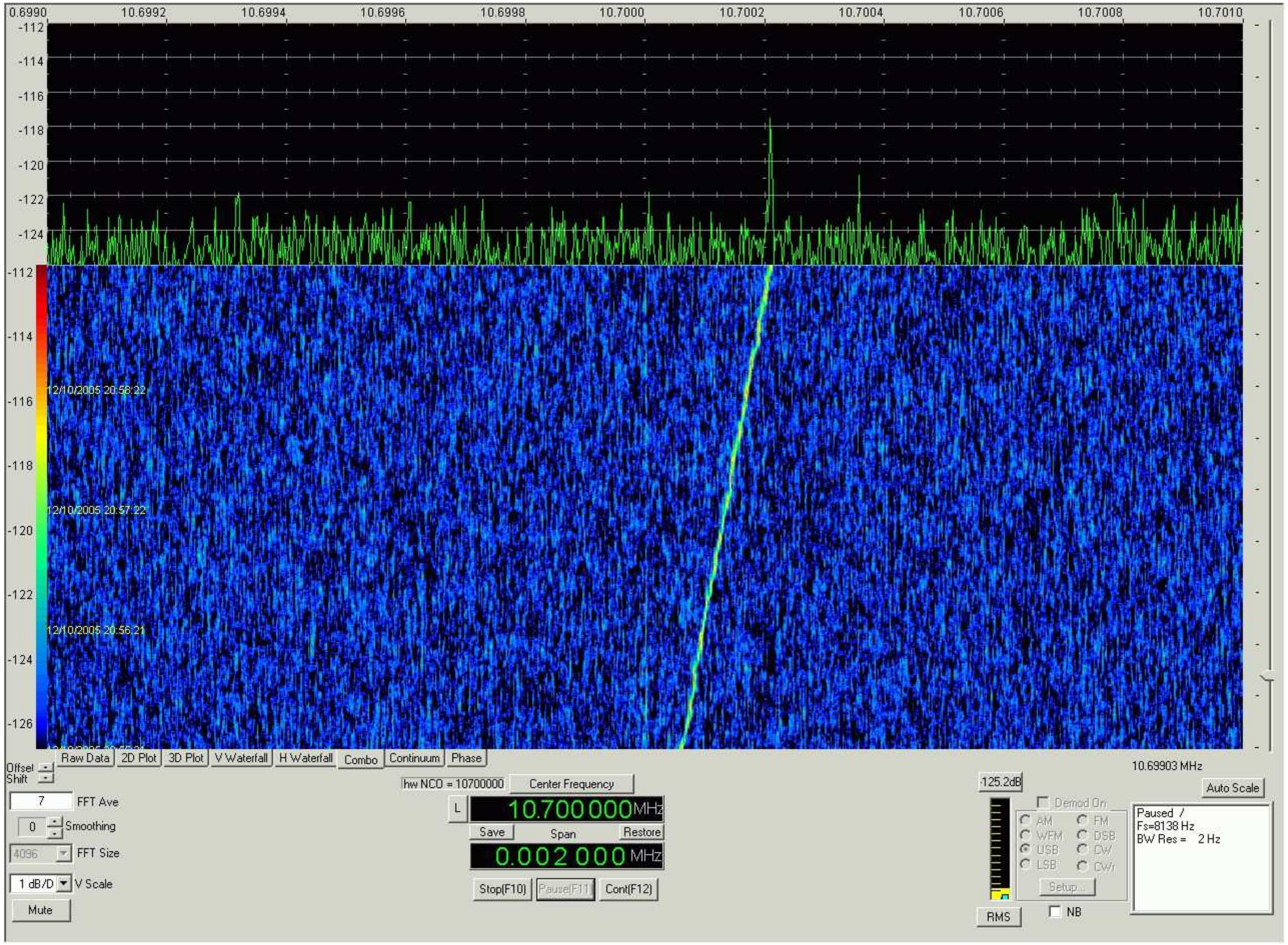
First signals at the M0EYT Earth Station

MRO’s location from a solar system perspective



First signals at the M0EYT Earth Station

The signal from MRO at just over 45 Million miles – not bad DX



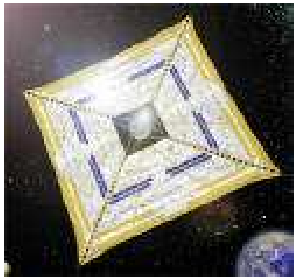
Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX’d so far
- Future
- Questions

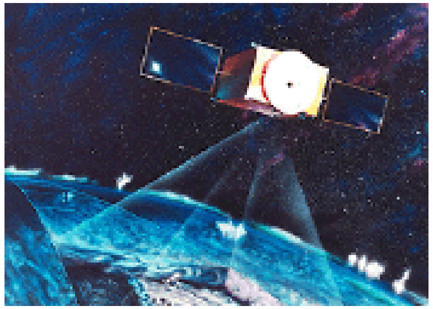
Space Craft DX'd so far

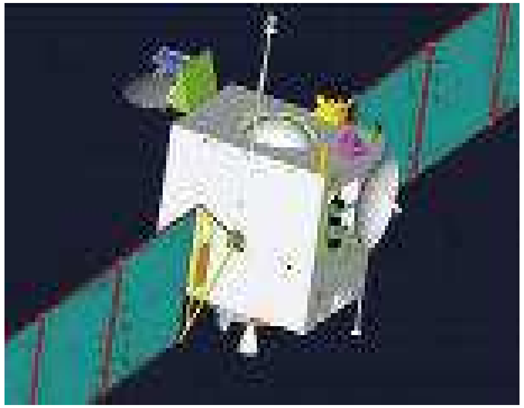
A selection of Space Craft downlinks received to date at M0EYT E/S





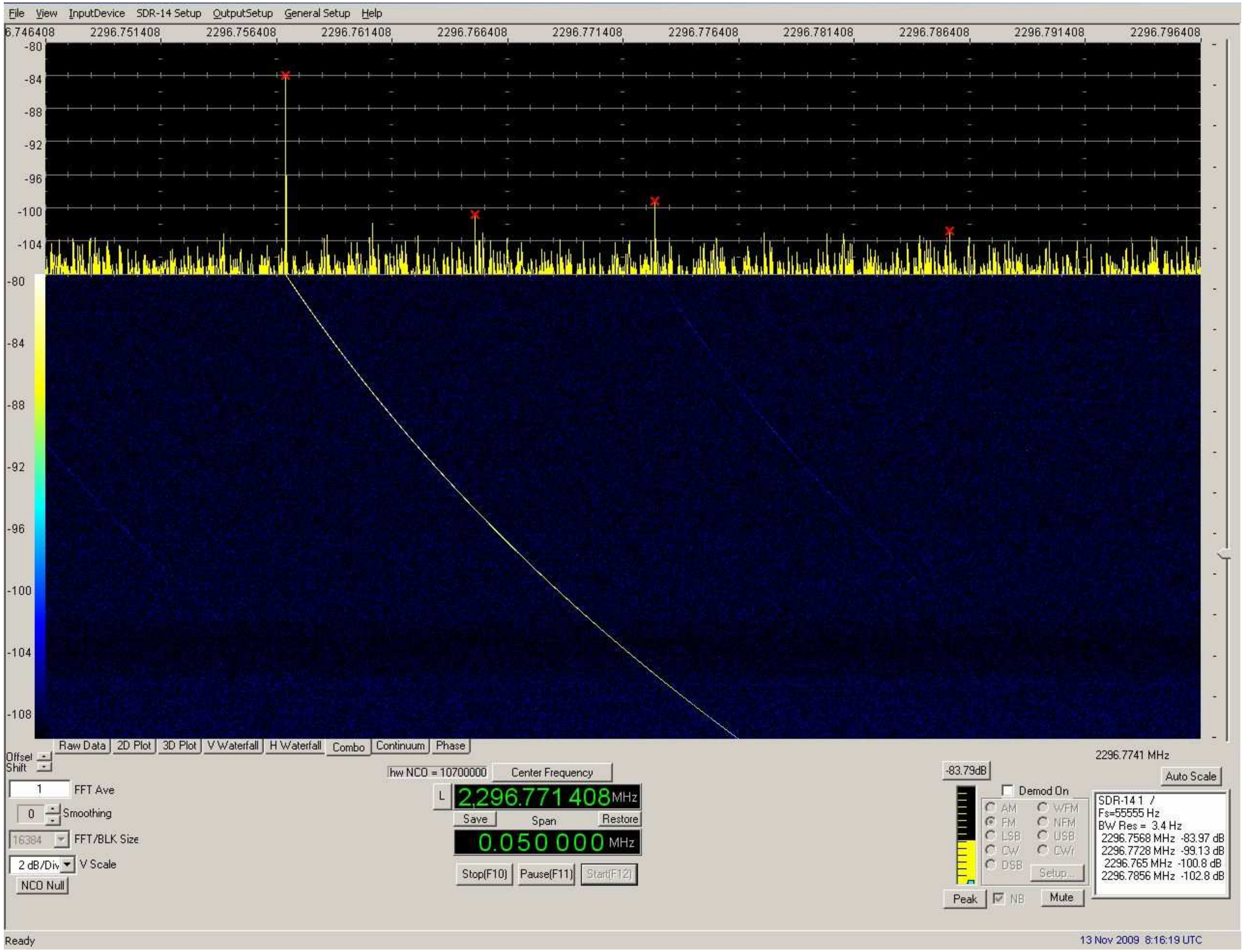


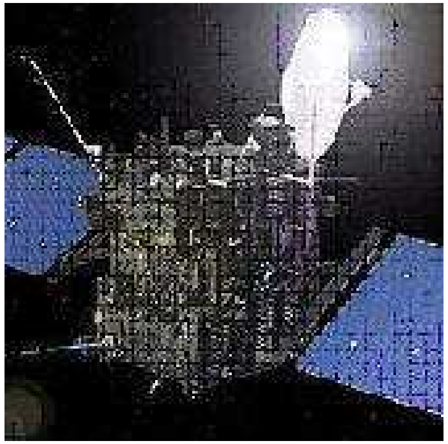





Space Craft DX'd so far

Rosetta: 12,153 miles away - 2296·770MHz – Earth Swing-By



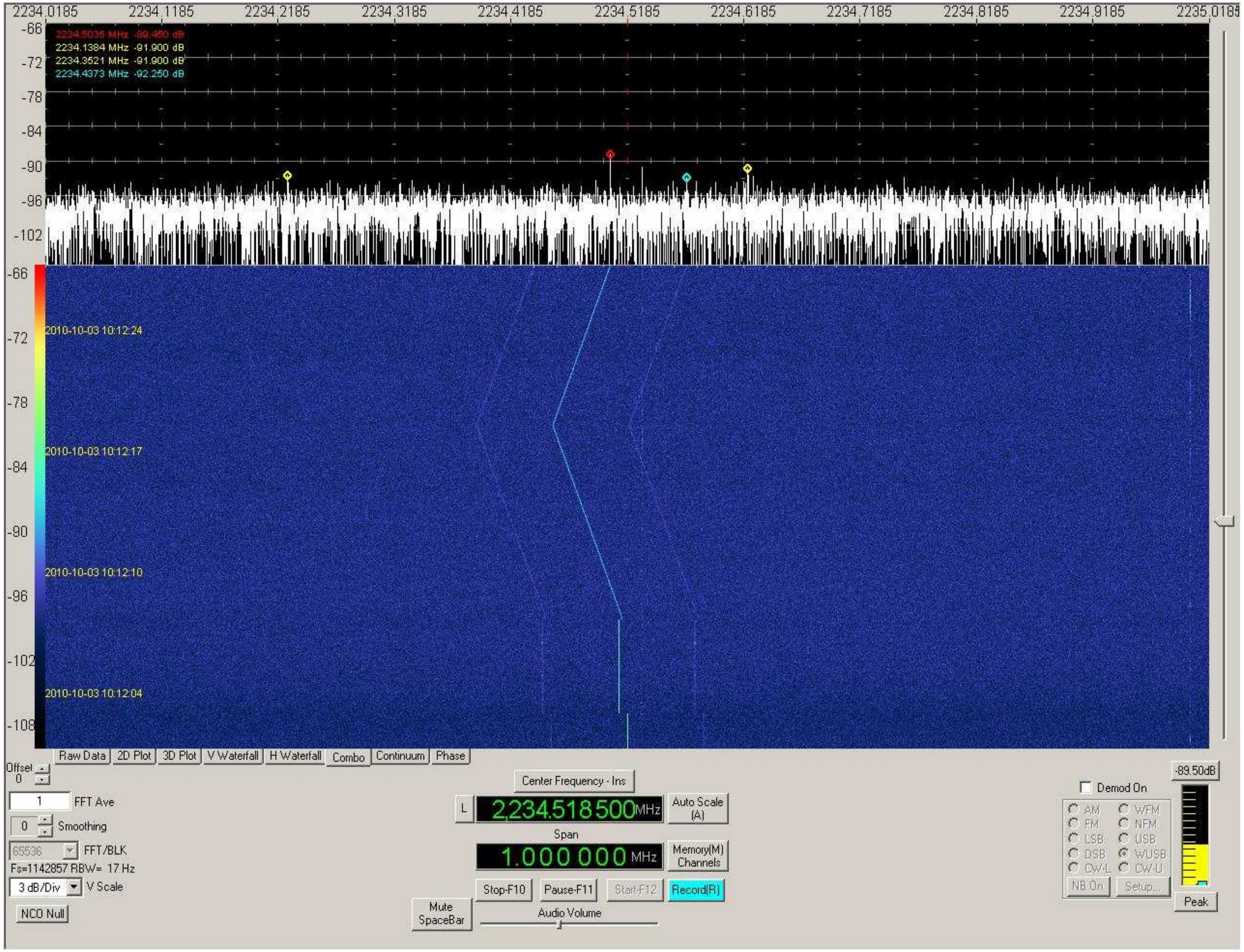


Launched: March the 2nd 2004

RF: LGA is omni with 5 watts of power at 2296.77 MHz

Space Craft DX'd so far

Chang'e'2: 200,000 miles away - 2234·533MHz



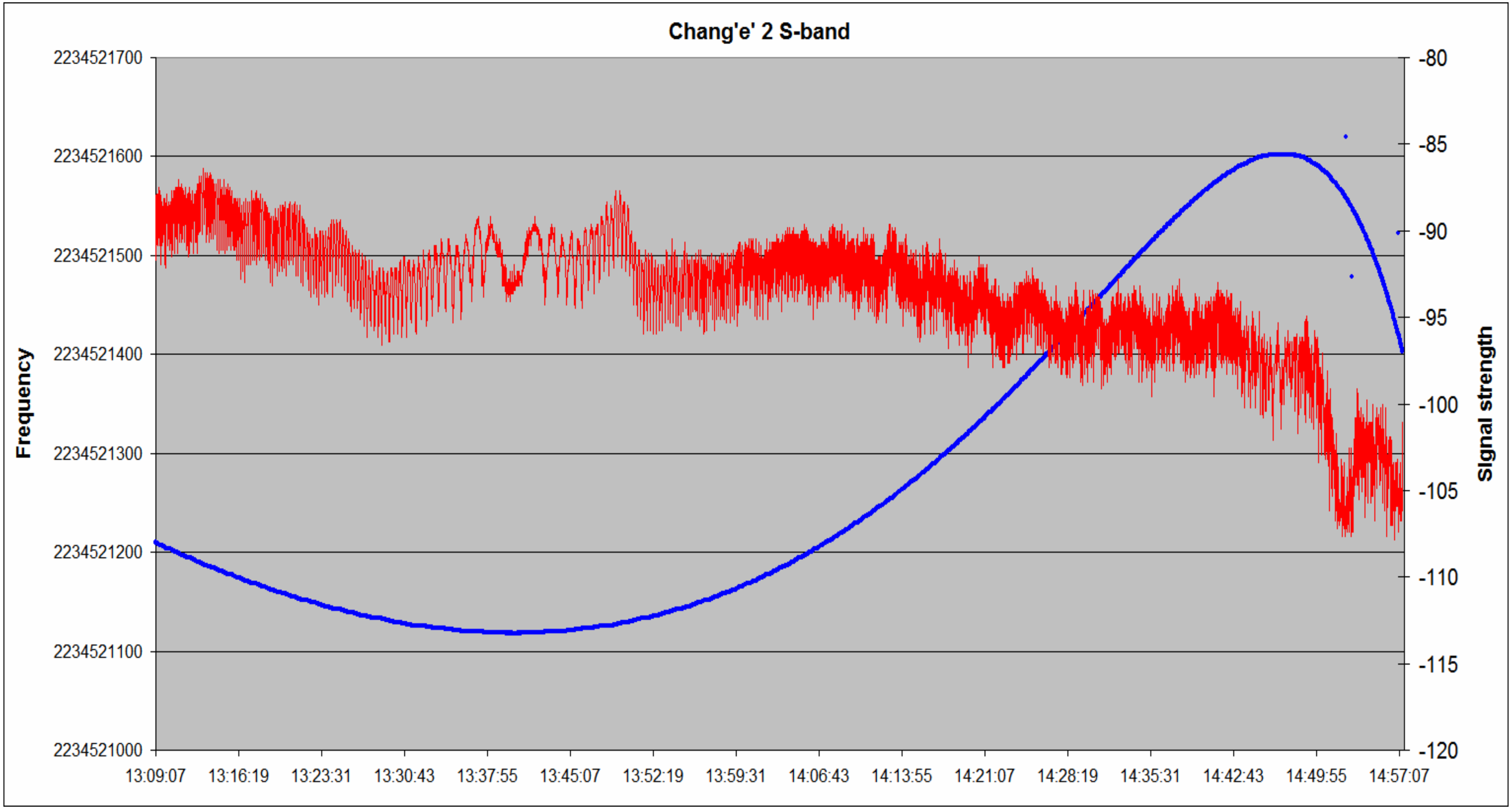
Launched: 1st October 2010

RF: S-Band omni, unknown power. 2234.533MHz and 2210.800MHz

X-Band dish, unknown power

Space Craft DX'd so far

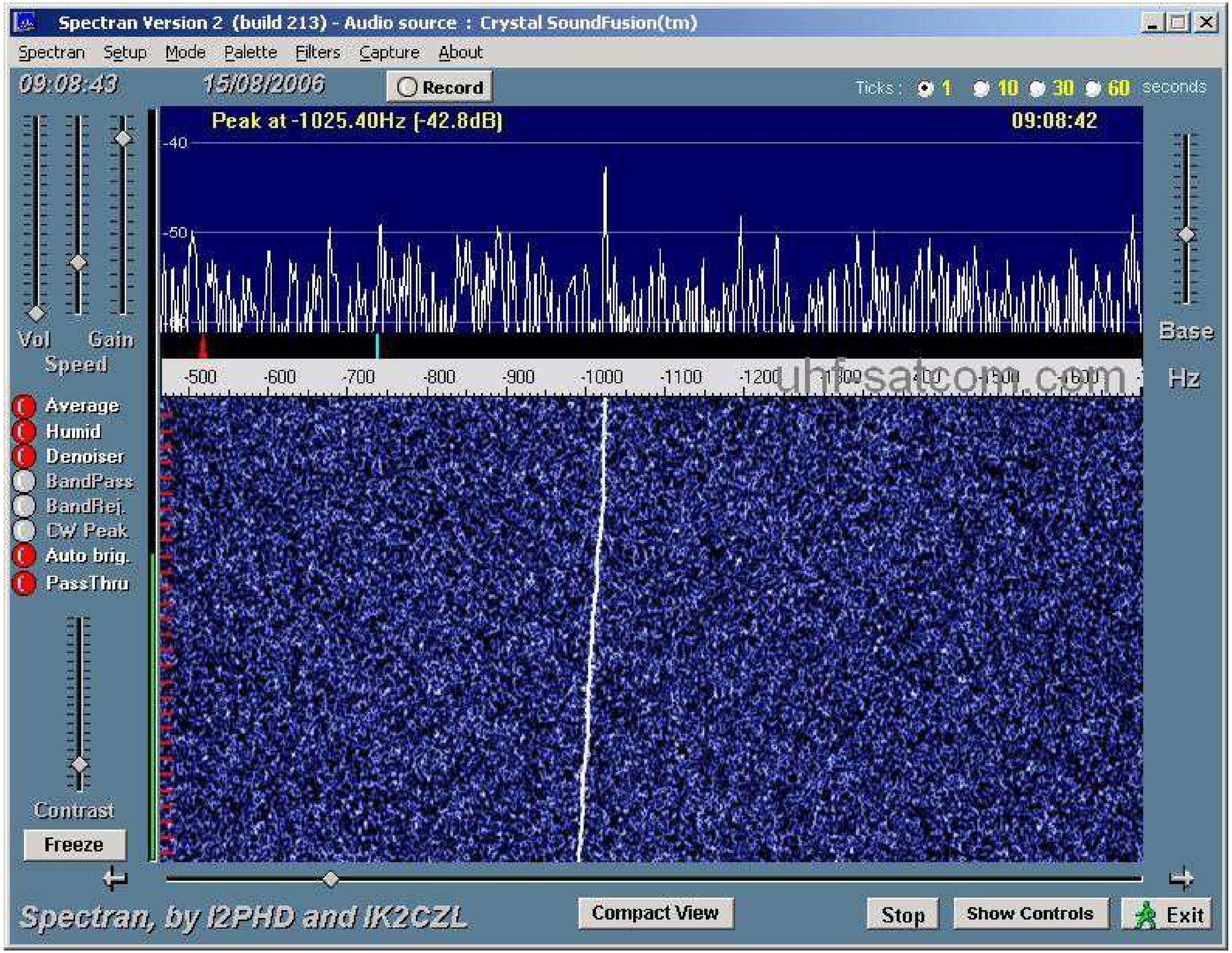
Chang'e'2: Lunar Orbit Insertion - 2234·533MHz – Doppler curve



Doppler Plot recorded on the 6th October 2010

Space Craft DX'd so far

Smart-1: Lunar Orbit - 8453·024225MHz



Launched: 27th September 2003

Mission end date: 3rd September 2006 (impact into moon)

RF: Horn antenna with +9dBm ERP at 8453.024225MHz

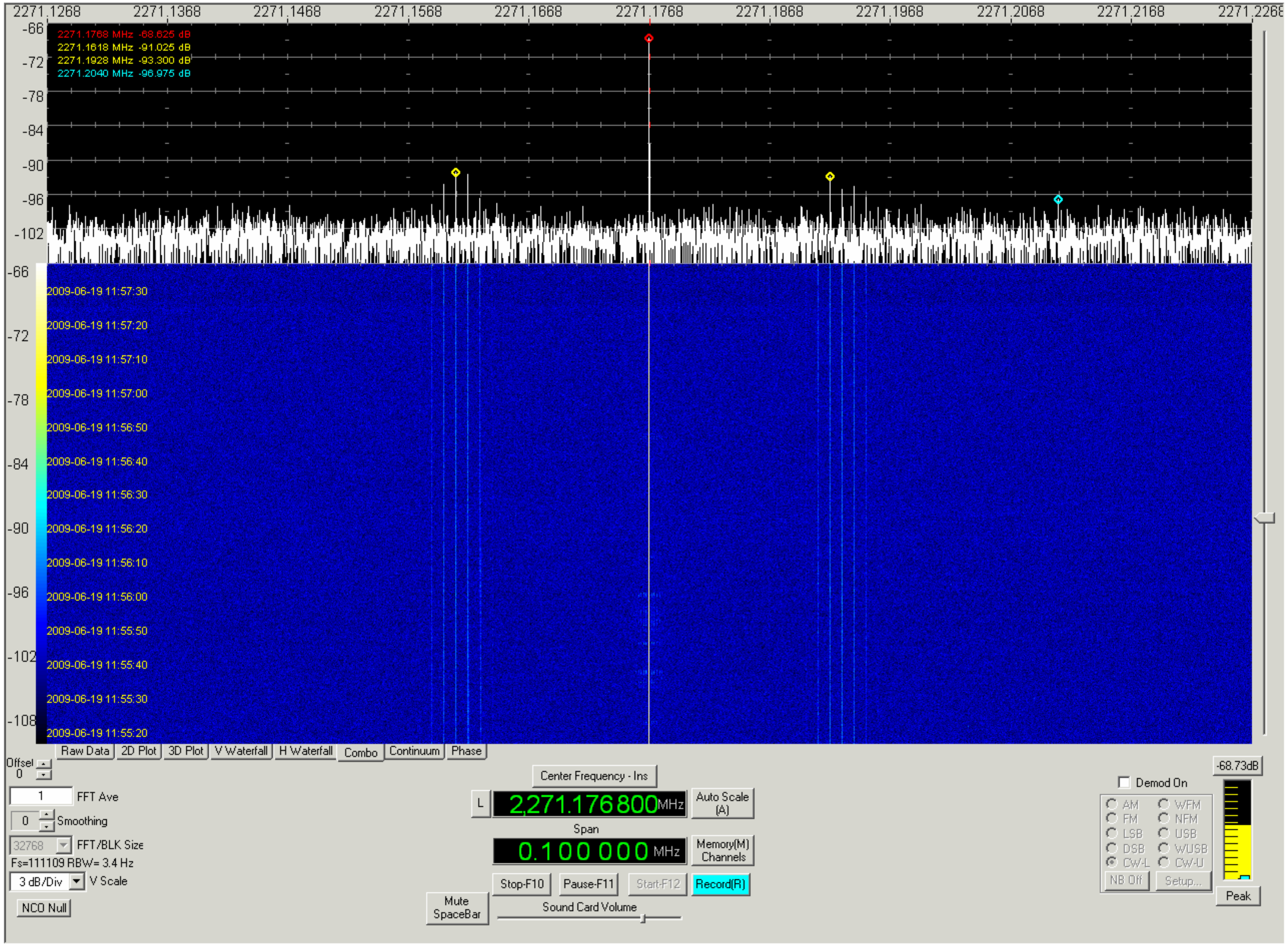
Space Craft DX'd so far

Smart-1: Lunar Orbit - 8453·024225MHz

Horn antenna with
+9dBm ERP at
8453.024225MHz

Space Craft DX'd so far

LRO: Lunar Orbit - 2271.200MHz

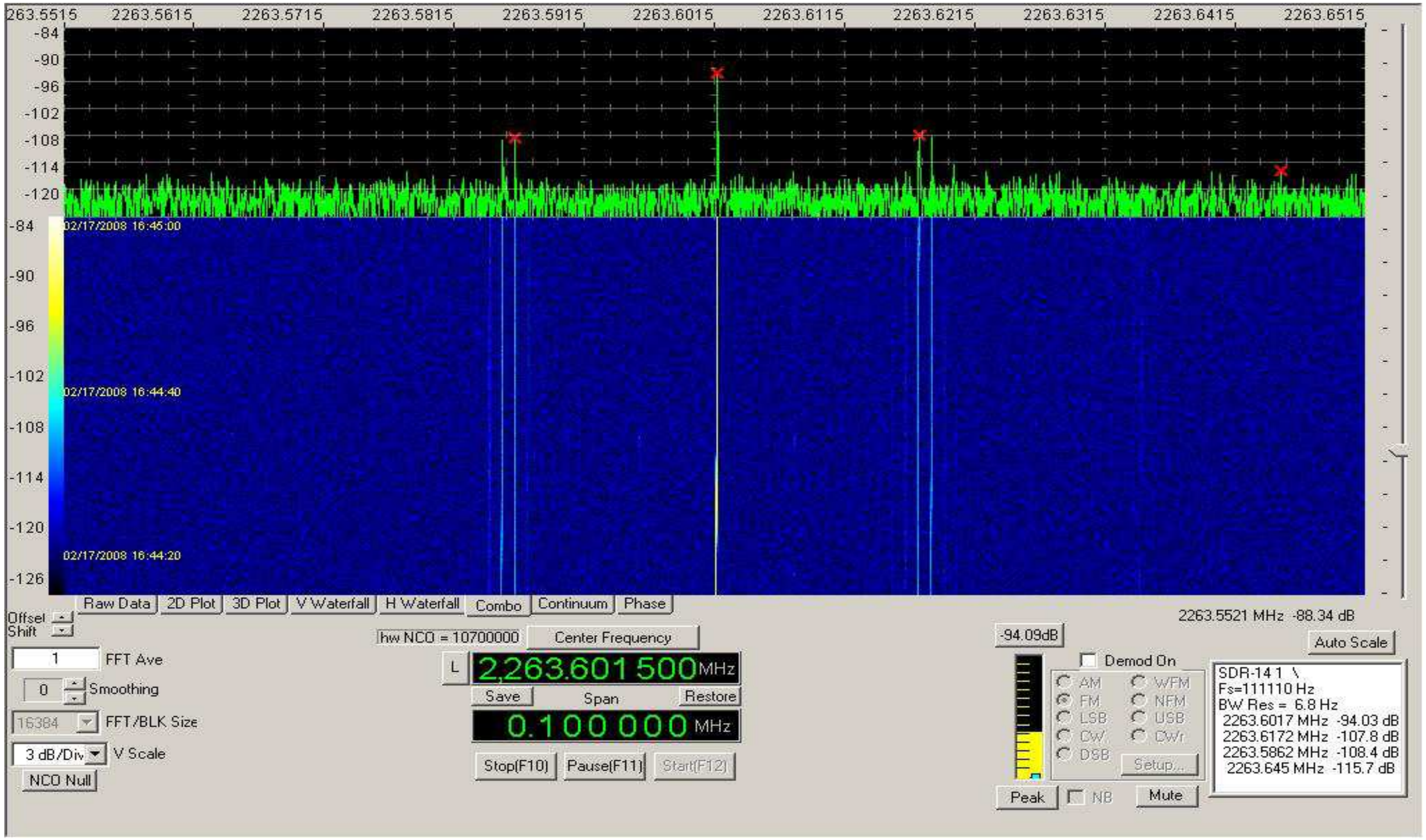


Launched: 18th June 2009

RF: Dish antenna with 21dB gain at 2271.2MHz and 44dB gain at 25650MHz

Space Craft DX'd so far

JAXA / Selene: Lunar Orbit - 2263·622MHz



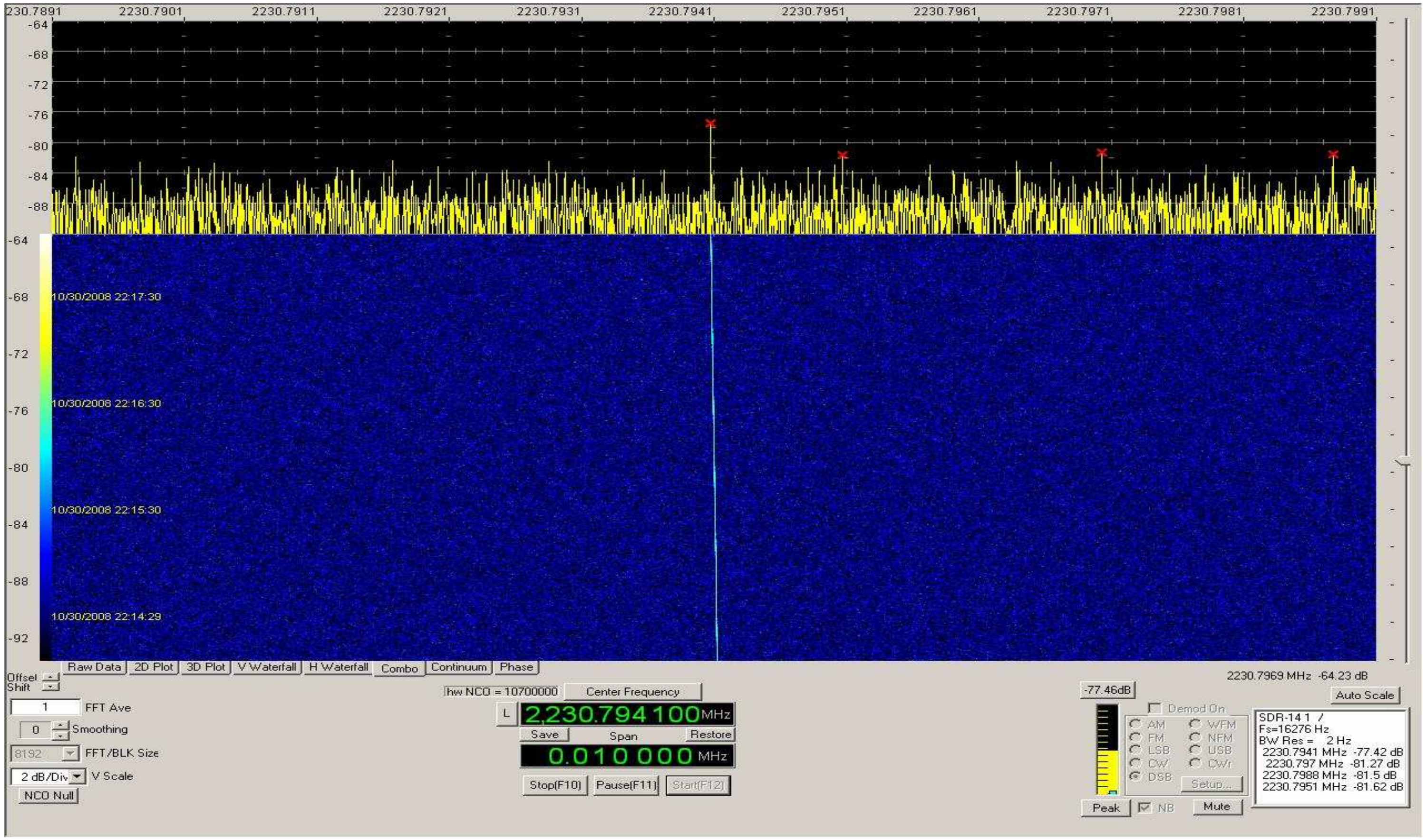
Launched: 14th September 2007

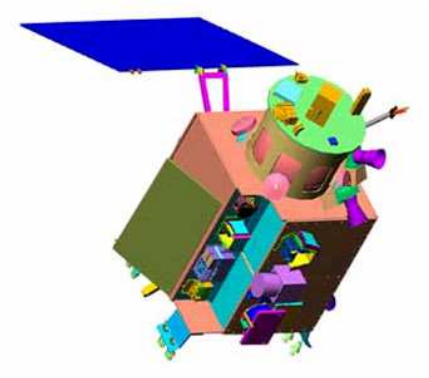
Impacted the moon on 10th June 2009

RF: Dish antenna with 4.6W & 25.4dB gain at 2263.6MHz

Space Craft DX'd so far

Chandrayaan-1: Lunar Orbit - 2230·8MHz





Launched: 22nd October 2008

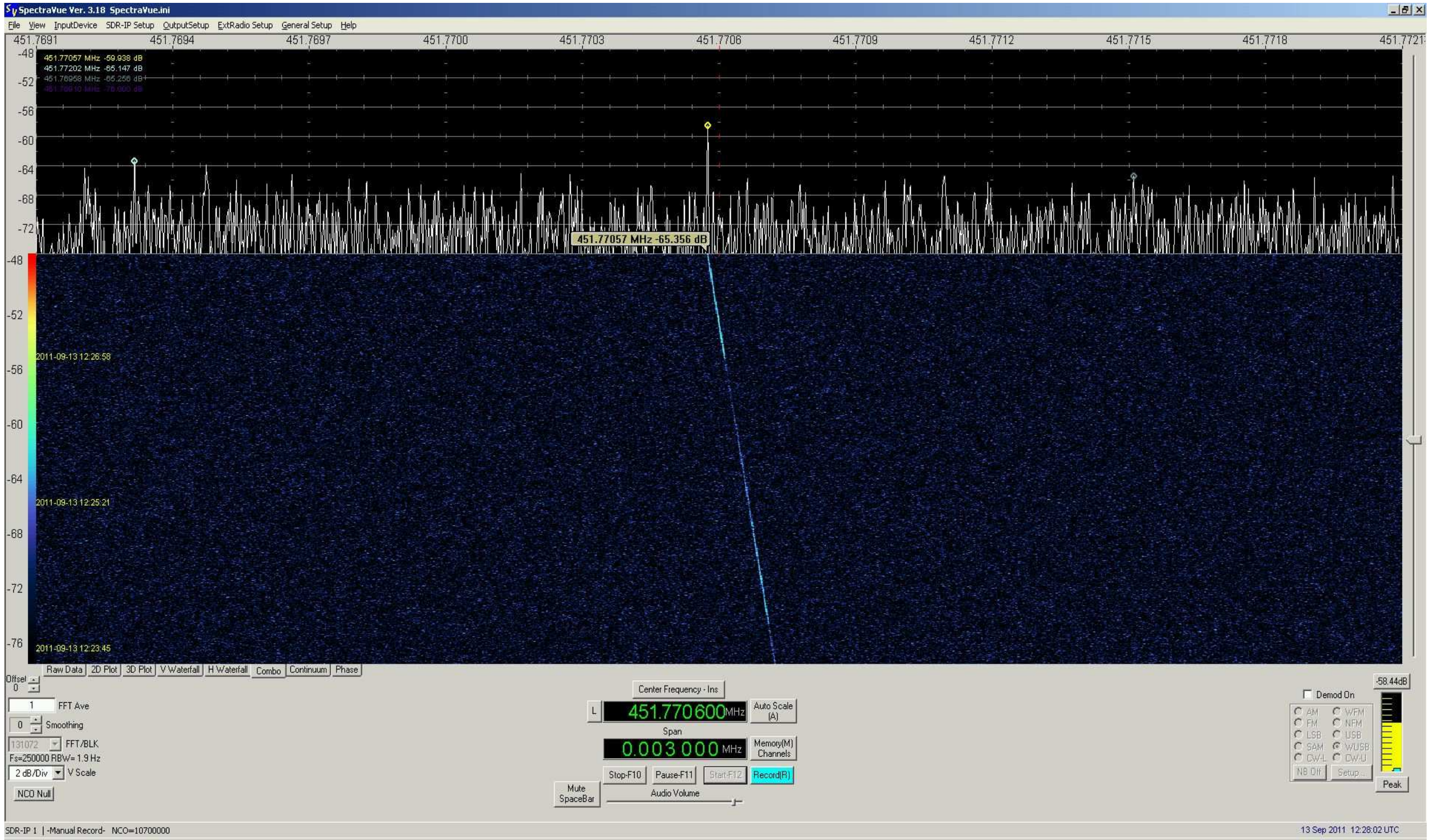
RF: Dish antenna with 5W & 22dB gain at 2230.8MHz

X-Band TX at 8484MHz

This is India's first moon orbiter!

Space Craft DX'd so far

NASA's Grail lunar orbiter 8451.770MHz

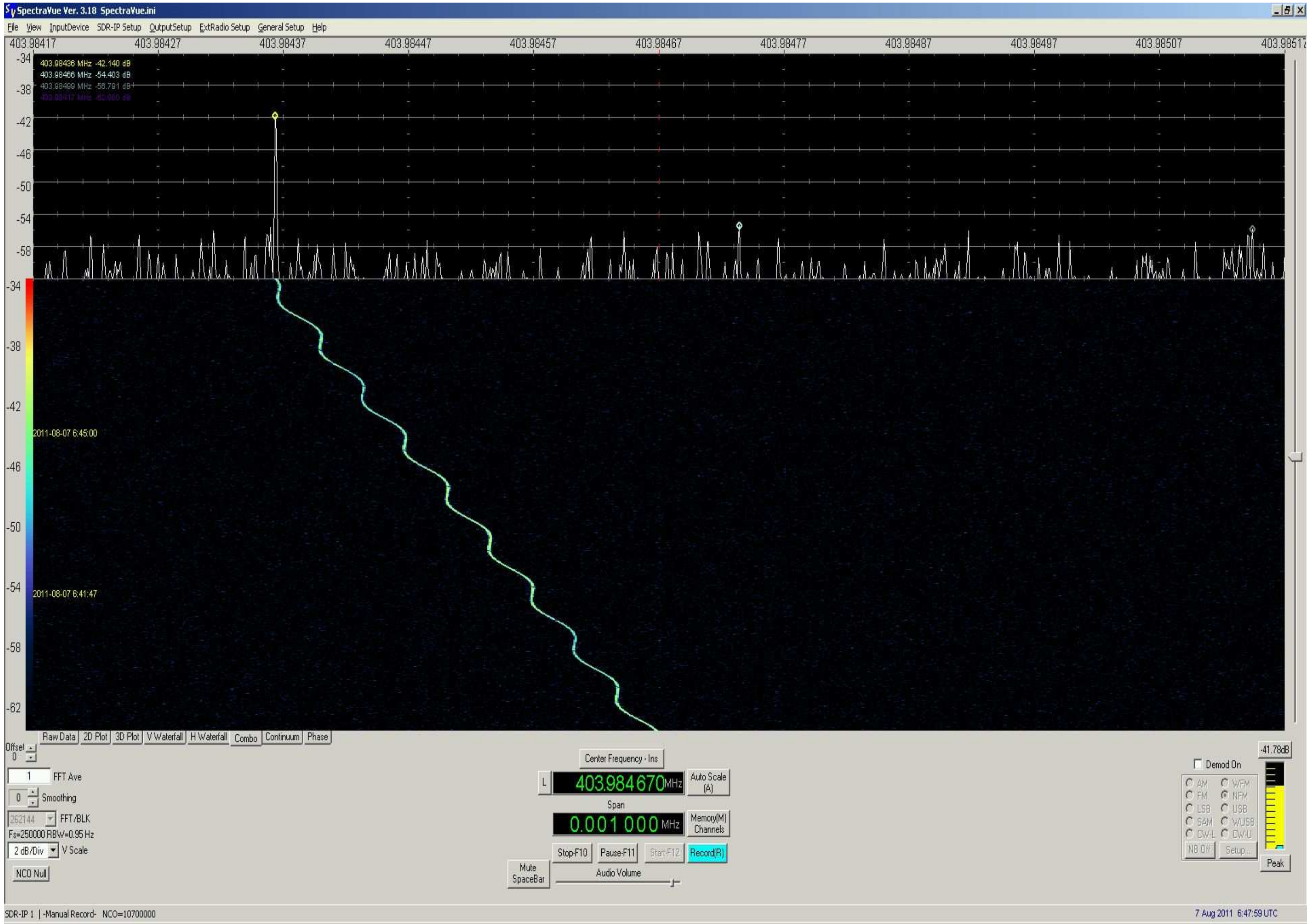


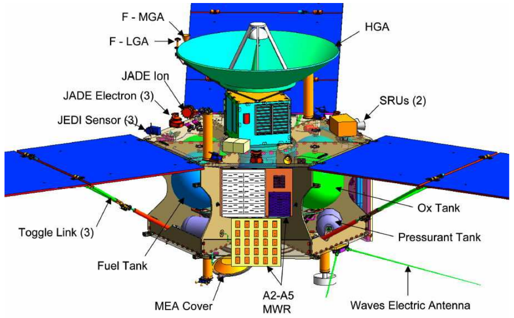
Launched: 10th September 2011

RF: Patch antenna with 120mW & 6dB gain at 8451MHz

Space Craft DX'd so far

NASA Juno: 490,761 miles away on - 8403·984MHz





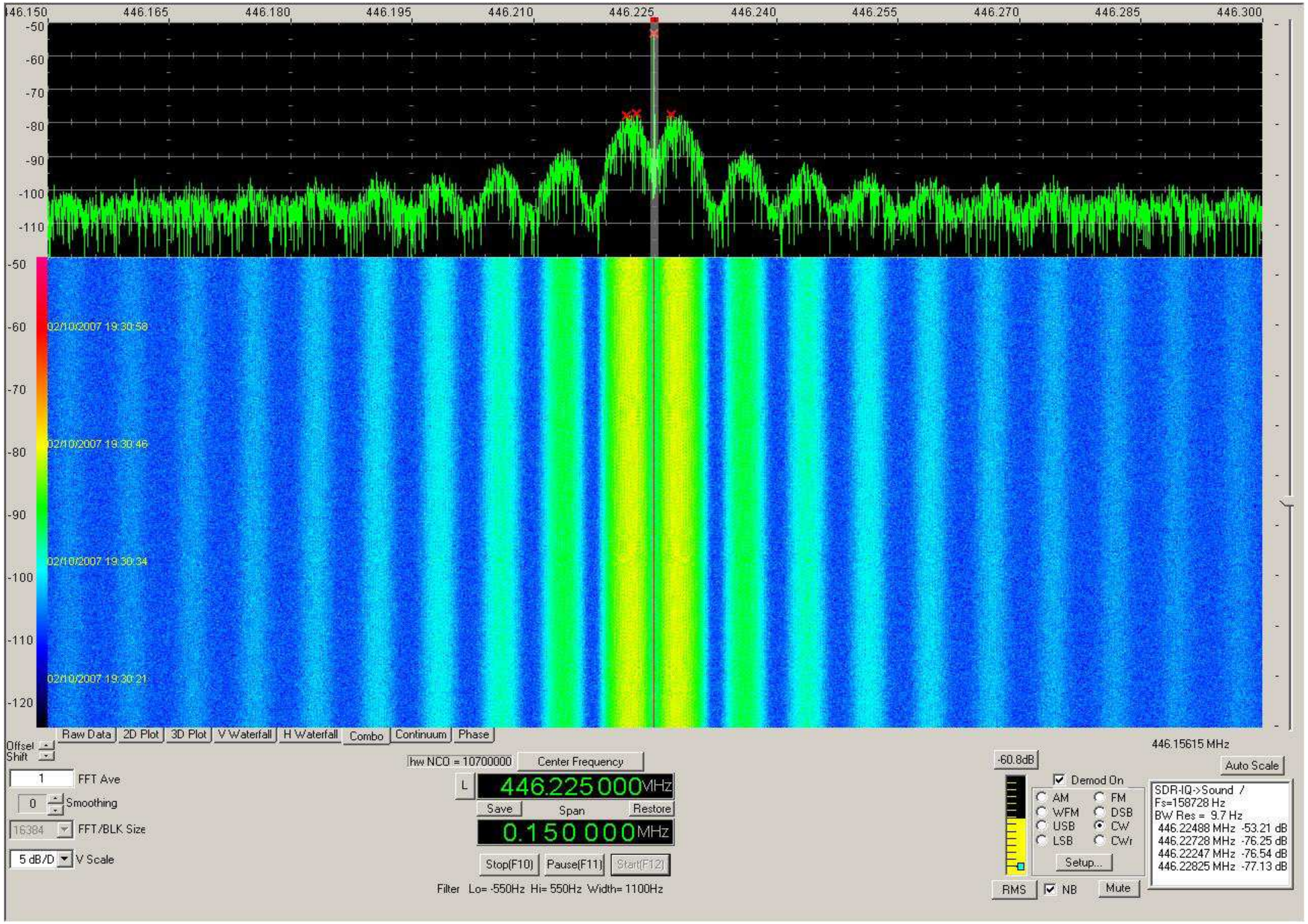
Launched from Cape Canaveral Air Force Station on the 5th August 2011

RF: 2.5m diameter dish with 45dB gain, 59dBw ERP at 8404.1358MHz

RF: 8.7dB gain horn with 23dBw ERP at 8404.1358MHz

Space Craft DX'd so far

Stereo-B: 743,043.96 miles away on - 8446·225MHz



Launched from Cape Canaveral Air Force Station on the 25th October 2006

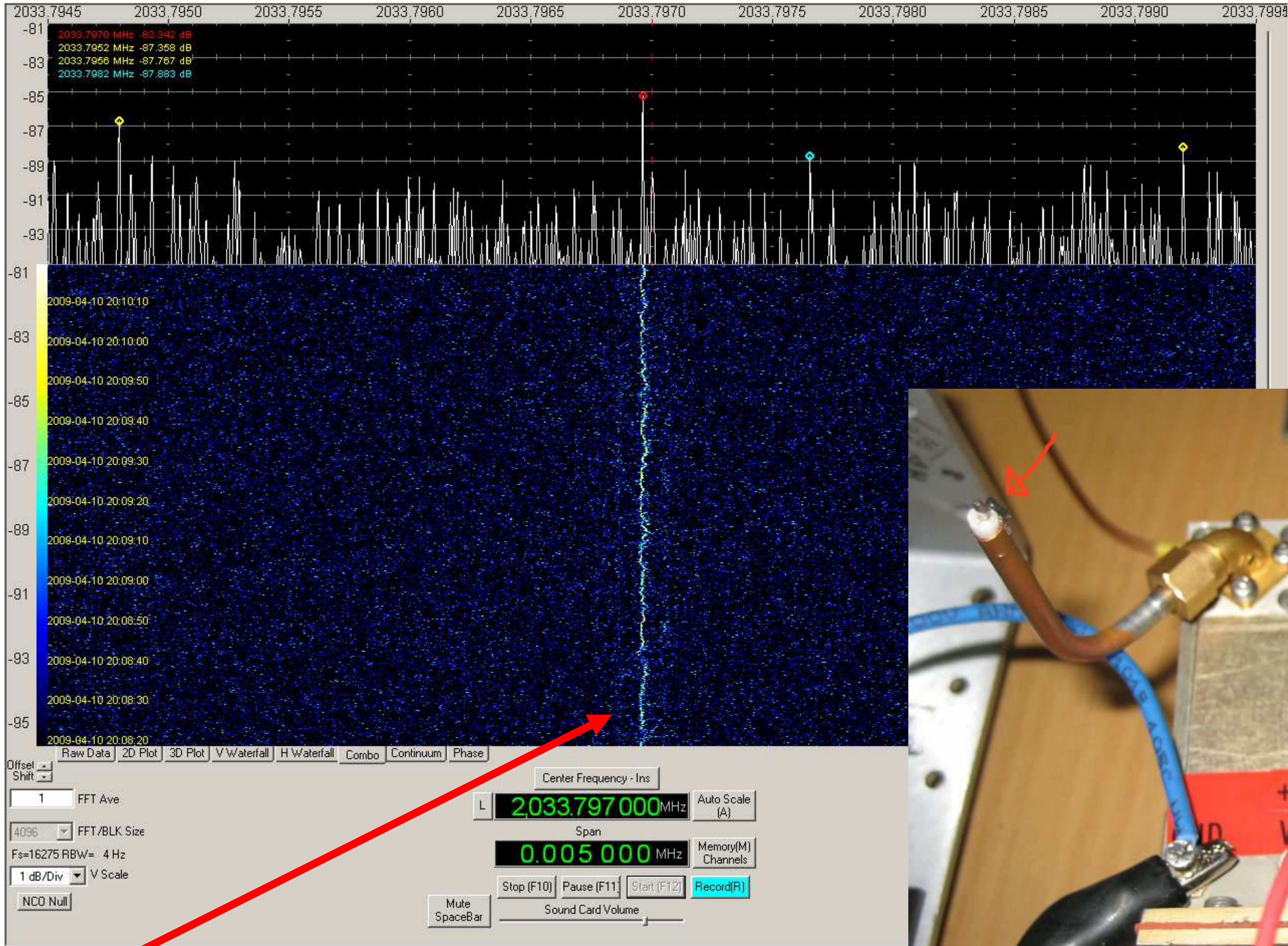
RF: Horn antenna with 6dB gain, 23dBw ERP at 8443.5185MHz & 8446.2345MHz

RF: 1.15m diameter dish with 37.9dB gain, 54.4dBw ERP at 8443.5185MHz & 8446.2345MHz

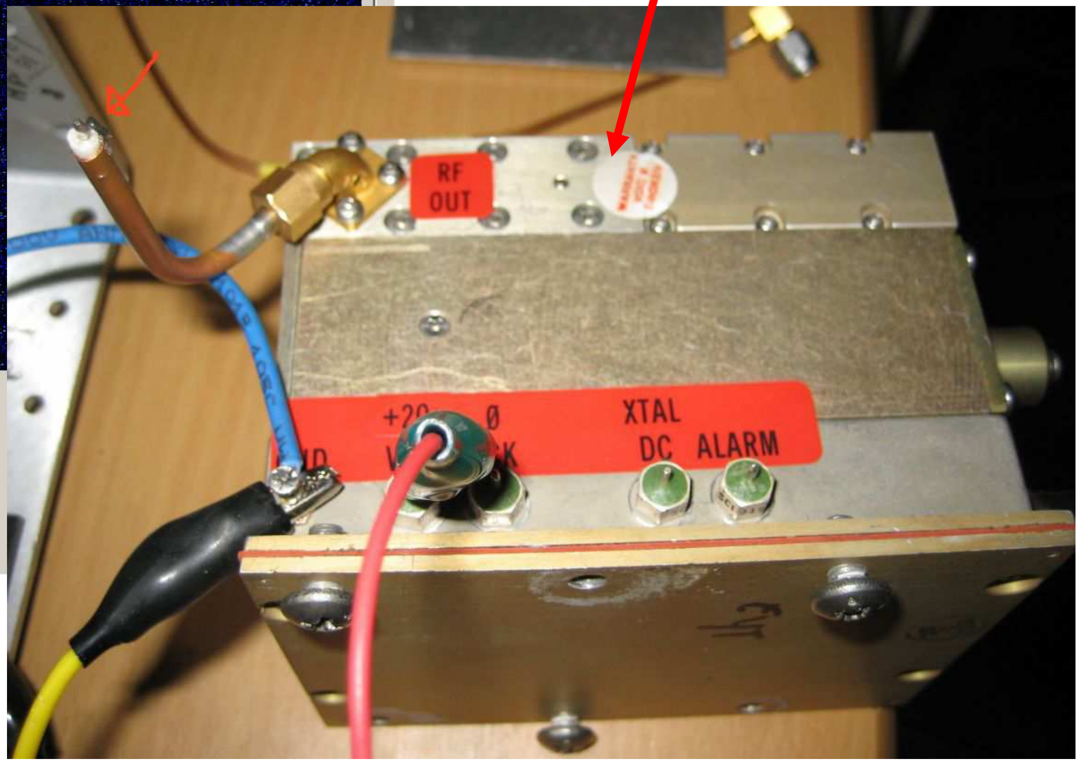
Signals copied from Stereo A&B on the day of launch!

Space Craft DX'd so far

Kepler: 3,226,045 miles away on - 32166·1711MHz



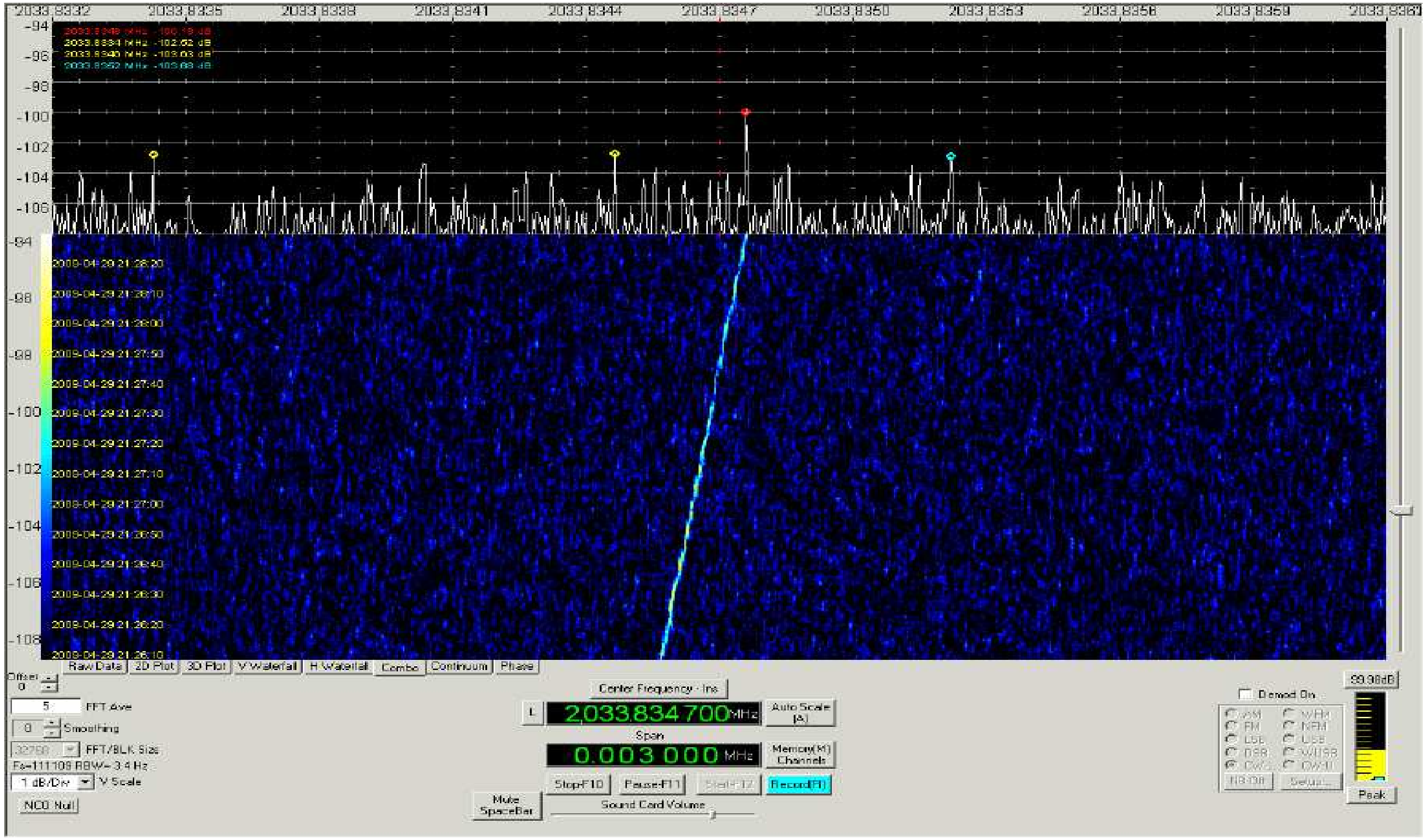
32GHz test source



Received signal (5KHz span)

Space Craft DX'd so far

Kepler: 3,226,045 miles away on - 32166·1711MHz



Launched: 6th March 2009

RF: Dish antenna 80cm with 35W & 46.6dB gain at 32166.29 MHz

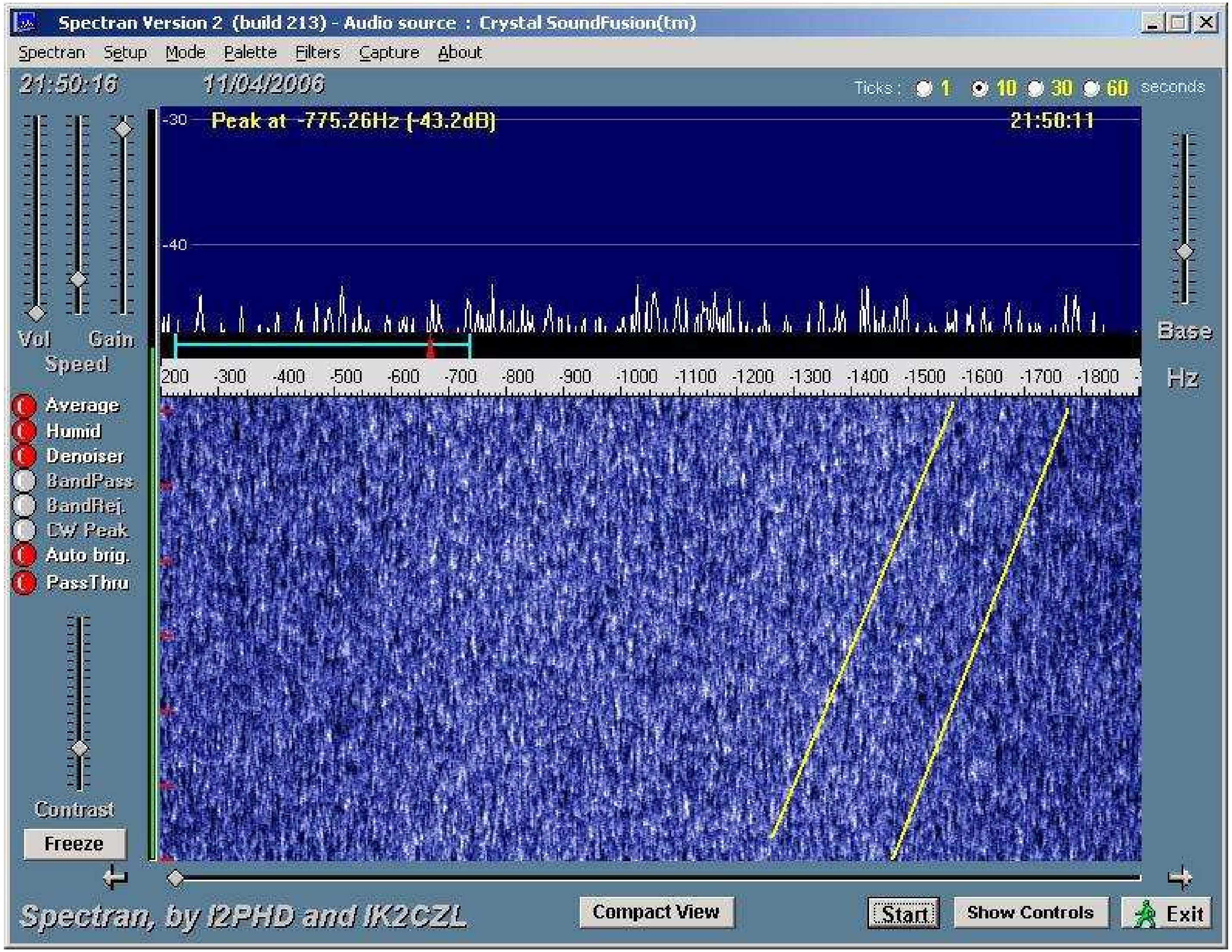
After 3½ weeks of checking, 2 hours per evening!

First Ka-Band DX @ M0EYT E/S

Kepler is Earth pointing once per month for data transfer

Space Craft DX'd so far

Mars Odyssey: 180,000,000 miles away - 8418·921MHz



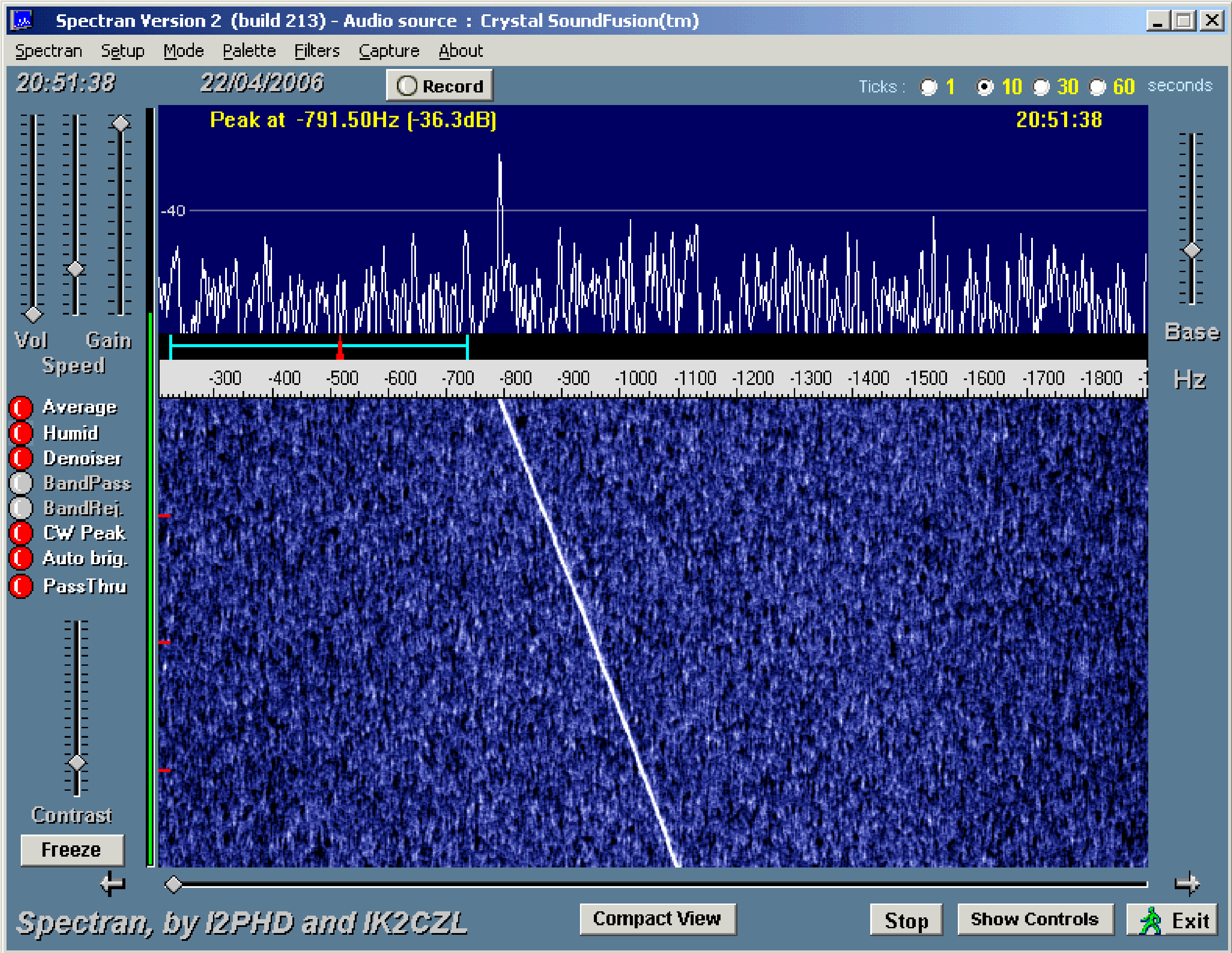
Launched: April the 7th 2001
Arrived Mars on October the 24th 2001

RF: HGA is 1.3m with 15 watts of power at 8406.851853 MHz

ERP: 107151 watts

Space Craft DX'd so far

Mars Express: 180,000,000 miles away - 8420·432097MHz



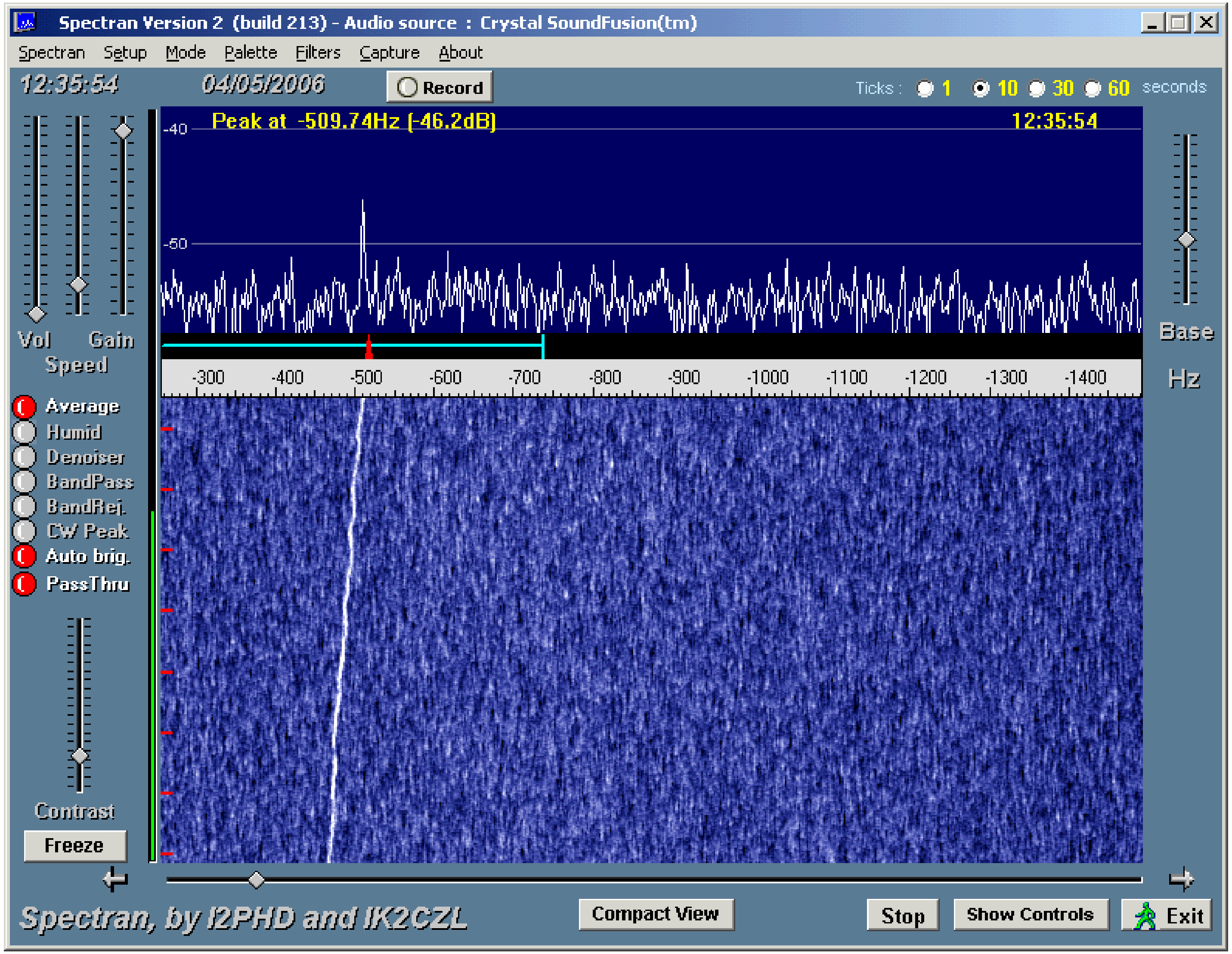
Launched: 2nd June 2003. Arrived at Mars in 25th December 2003

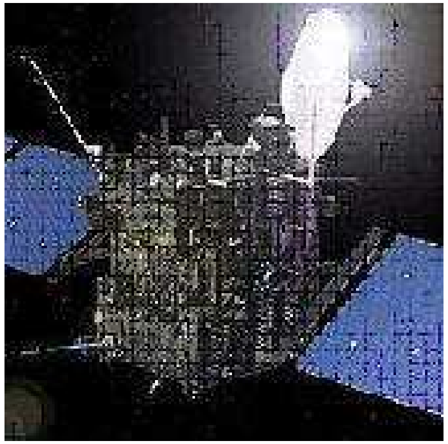
RF: HGA is 1.6m 65w of power at 8420.432097 MHz

ERP: 630957 watts

Space Craft DX'd so far

Rosetta: 233,830,357 miles away - 8421·790123MHz





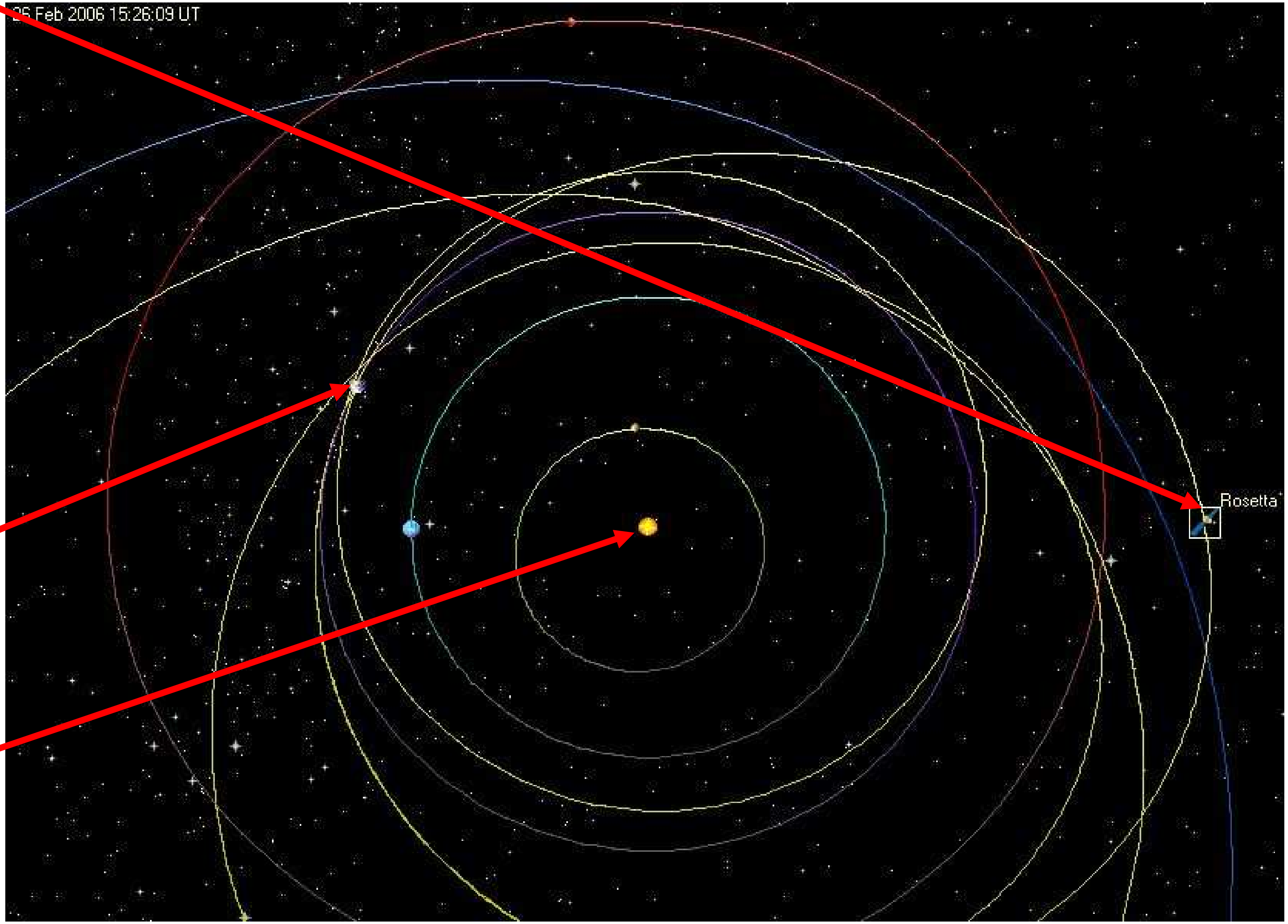
Launched: March the 2nd 2004

RF: HGA is 2.2m with 28 watts of power at 8421.790123 MHz

ERP: 467735 watts

Space Craft DX'd so far

Rosetta: 233,830,357 miles away - 8421·790123MHz

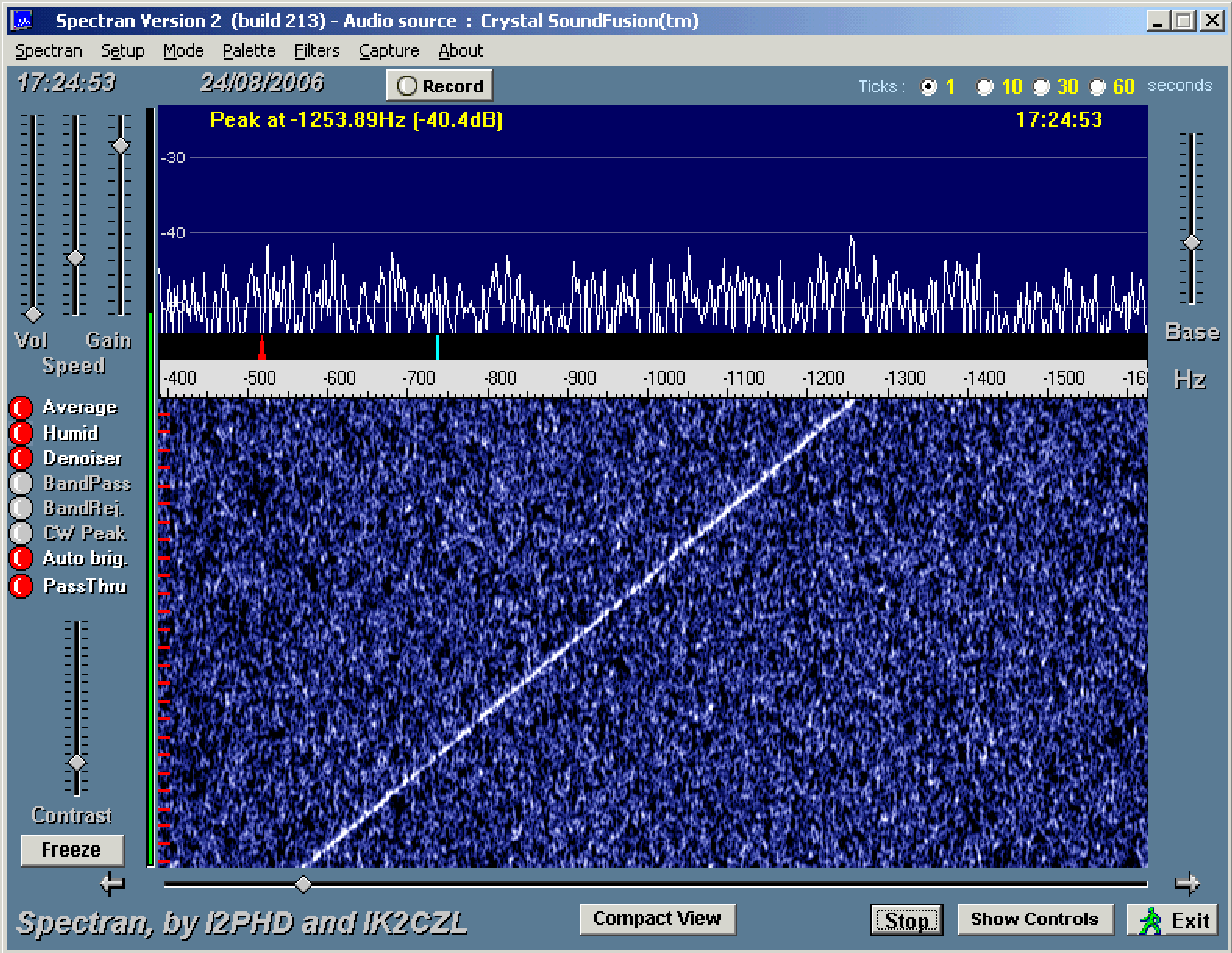


M0EYT

SUN

Space Craft DX'd so far

MRO: 238,335,939 miles away - 8439·444446MHz



Launched : 12th August 2006

Arrived at Mars on 10th March 2006

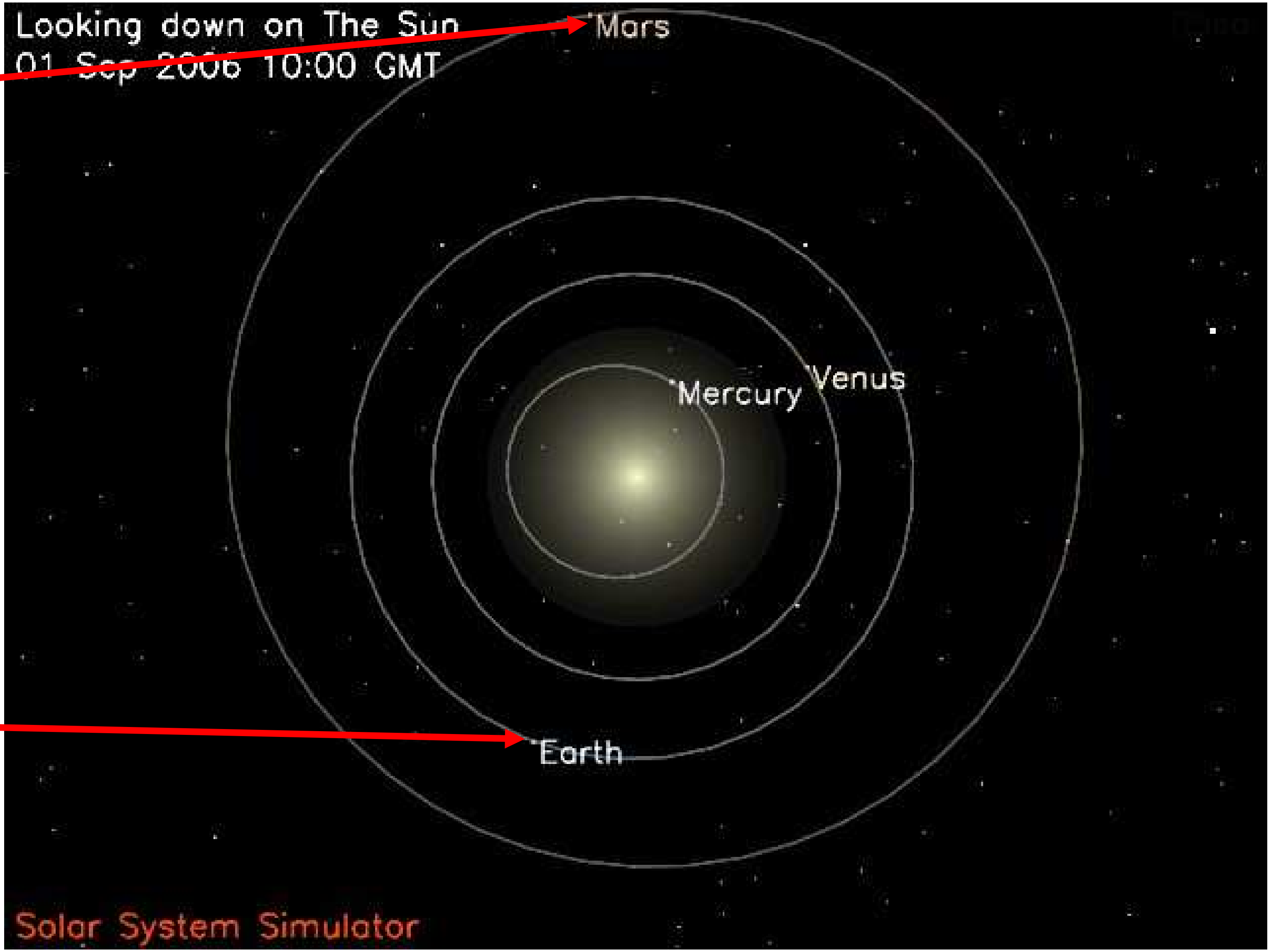
RF: HGA is 3m with 100 watts @ 8439.444446 MHz

ERP: 3467368 watts

Space Craft DX'd so far

MRO: 238,335,939 miles away - 8439·444446MHz

MRO



M0EYT

Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX’d so far
- Future
- Questions

Future

What is the future of Amateur DSN ?

- New missions are being launched all the time, so there are new space-craft to DX – the most recent launch is NASA’s MSL which transmits on UHF & X band 8401.4198MHz

- Amateur DSN provides an excellent learning environment to prepare for missions such as the AMSAT Mars mission

- Continually weakening signals provide opportunity for system optimisation and some exceptional DX at microwave frequencies

- Data demodulation and decoding is possible – amateur stations are currently taking STEREO-A/B data for NASA!

Future

What is the future of Amateur DSN ?

• Amateur Radio missions such as the failed Japanese UNITEC-1 deep space mission may be repeated

• Advances in signal processing may lead to the demodulation and decoding of science data

• More stations will be ‘on air’ providing observations of deep space probes, that can be useful to space agencies such as ESA and NASA. ESA feedback from ‘techies’ has been encouraging.

Agenda

- Introduction
- My background
- The inspiration for this project
- Professional DSN ground stations
- Frequency References
- Receive Systems
- Antenna Pointing
- Signal Detection Methods
- First signals at the M0EYT Earth Station
- Space Craft DX’d so far
- Future
- Questions

Questions ?

Satcom and DSN related updates can be found at;

http://www.twitter.com/UHF_Satcom